On the summer 2021 hailstorms in Switzerland: major impacts and unique observational data

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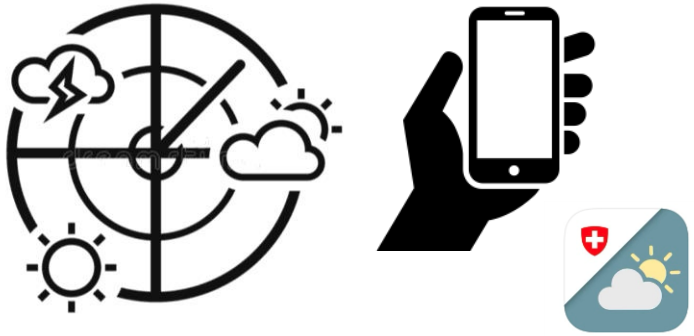
In a nutshell

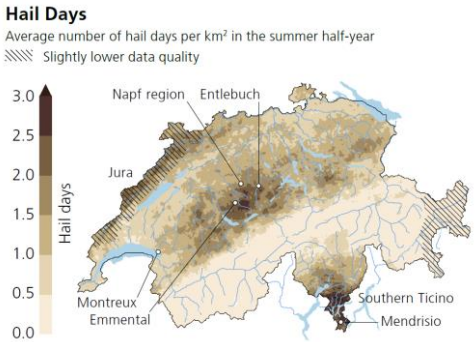
- Between 18 June and 31 July 2021, widespread and intense hailstorms occurred over Switzerland

  → **historical damages to buildings, cars and crops**.

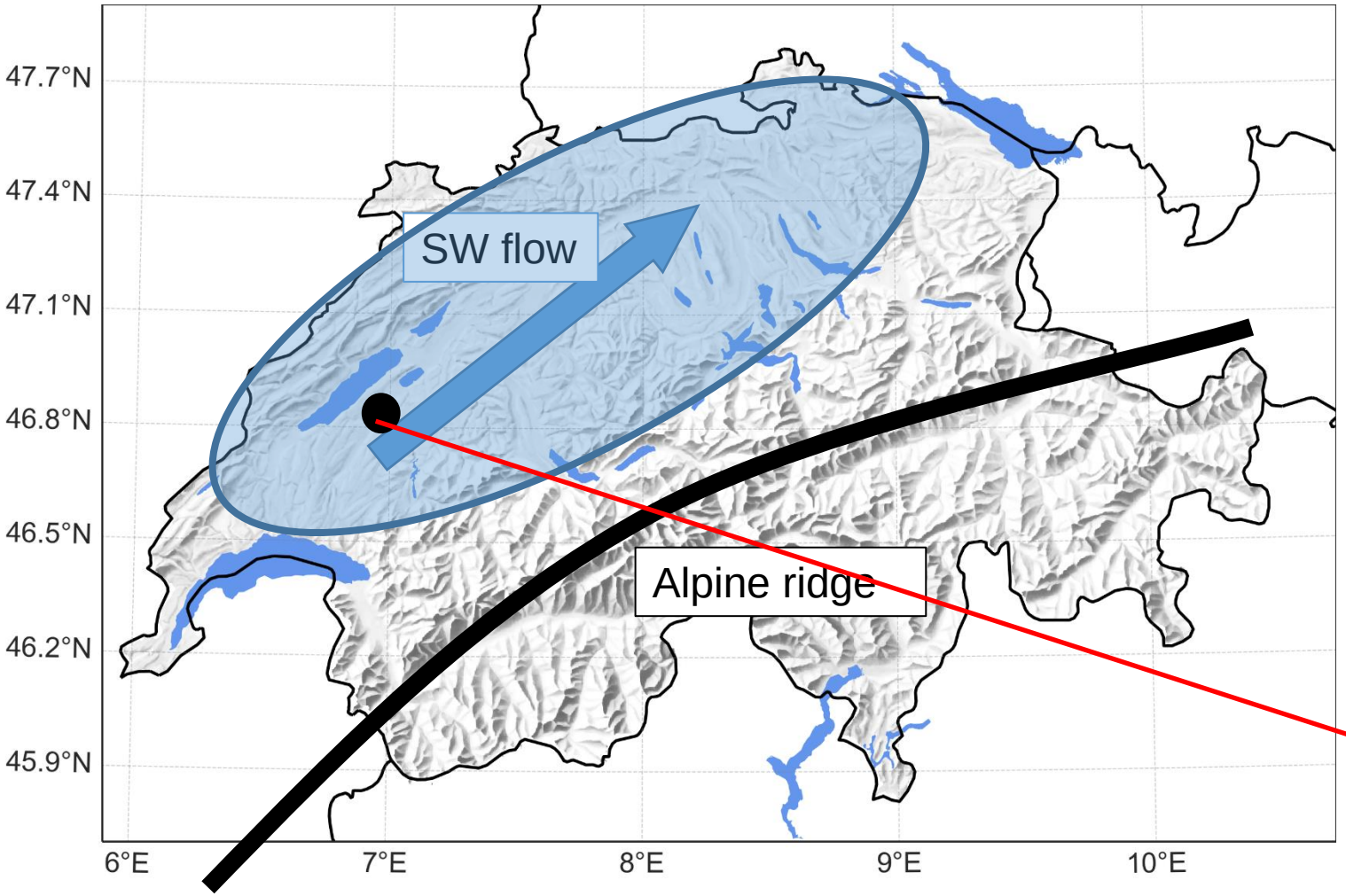


- Captured by **unique combination of 3 hail observing systems in Switzerland**: 5 dual-pol radars, MeteoSwiss crowdsourced report function (2015), 80 automatic hail sensors (2018)

- Swiss radar-based hail climatology (2002-2021) → **rare events**
- **Focus on 28 June: most severe impact**



28.06.2021 – Weather situation



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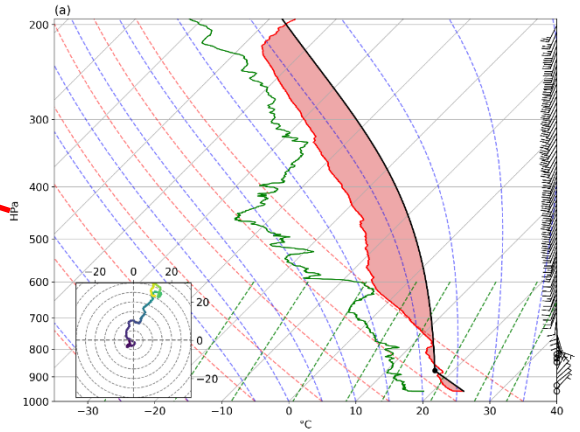
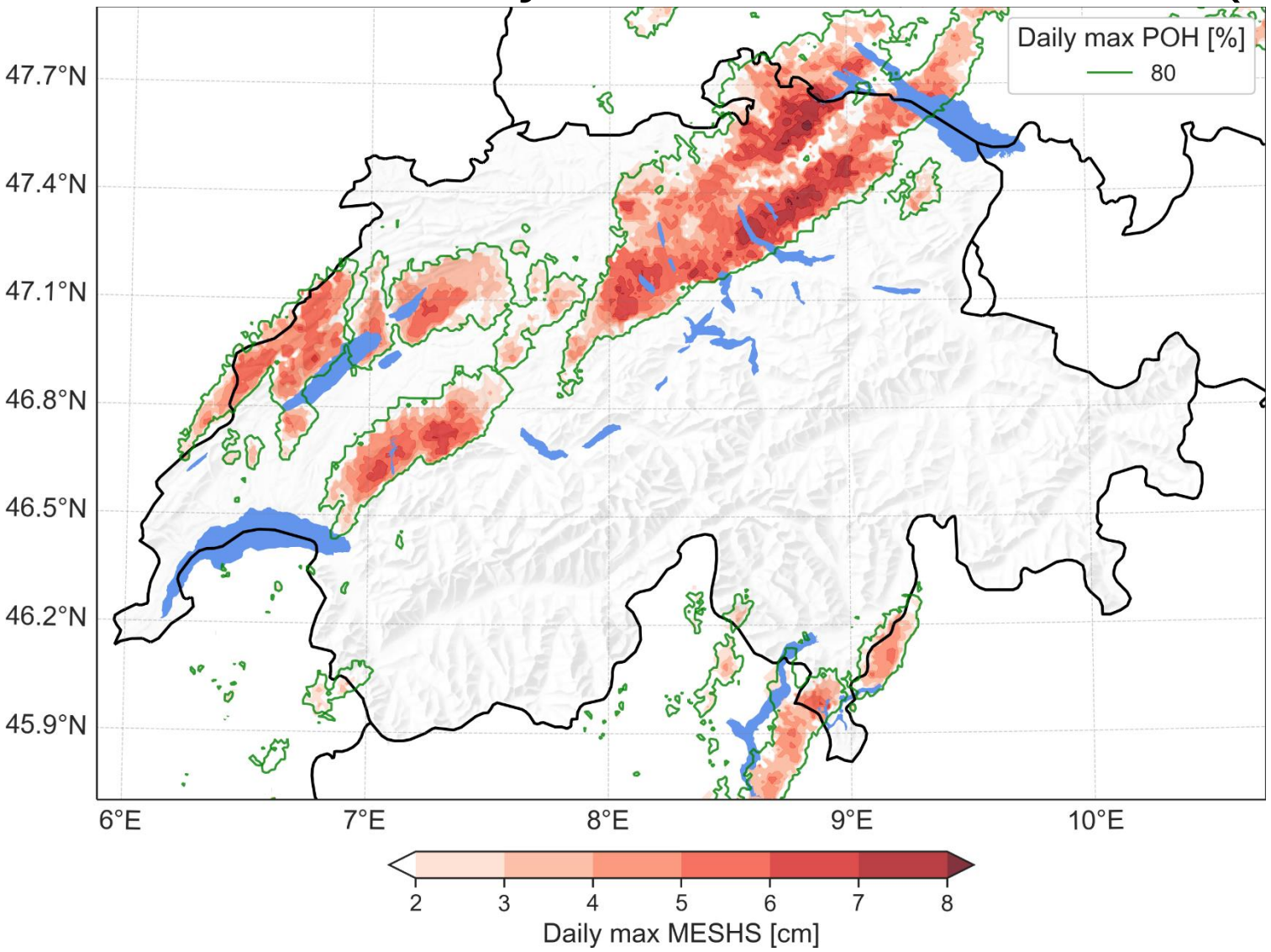


Payerne meteorological sounding

- High CAPE, bulk and directional shear, high moisture content
- Conditions favourable to hailstorms over northern Prealpine region (blue)

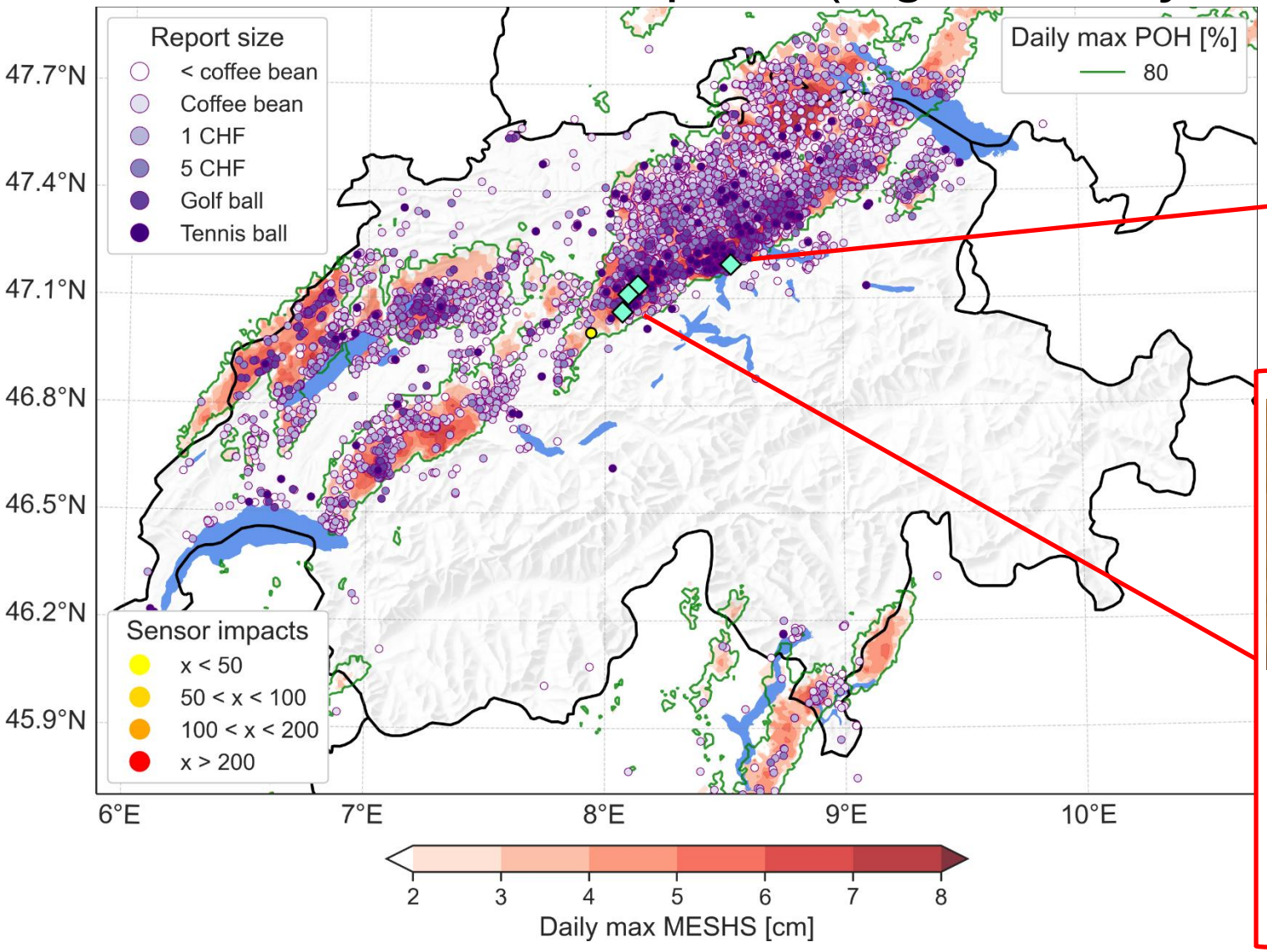
28.06.2021 – Daily Max POH and MESHS (radar-based)



- POH (green contours): where hail is very likely
- MESHS (red colorscale): size of largest hailstone over an area of 1km^2

POH: Probability Of Hail
MESHS: Maximum Expected Severe Hail Size

28.06.2021 ~ 11’000 reports (highest daily number)



Picture source: Sturmarchiv Schweiz / www.sturmarchiv.ch, *© Bettina Mosel, Baar (top); © M. Kost, Wolhusen via SRF (middle); © Roland Müller, Nottwil via SRF (right); Leserreporter Luzerner Zeitung, Ruswil (bottom)*

Wrap up

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June 28 2021:

- All ingredients for severe convection were present
- Largest number of daily crowdsourced reports (11’000)
- Largest areas for severe (>2cm) and extreme hail (>4cm), and 2nd largest hail-affected area (POH>80%) since 2002
- Hailstones of up to 9 cm diameter (local return periods of 70-100 years)
- Comparison between radar/crowdsourced/sensor data in progress

- Detailed material available online: weather situation, daily analysis, automatic hail sensors measurements (https://meetingorganizer.copernicus.org/EGU22/session/43873)
- Publication submitted to Weather journal (28 June and 8 July, weather description, climatological analysis, hail data analysis)
- Swiss hail climatology: www.hailclimatology.ch
- Contact: jerome.kopp@giub.unibe.ch

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Hail observing systems in Switzerland

Unique combination of 3 hail observing systems in Switzerland

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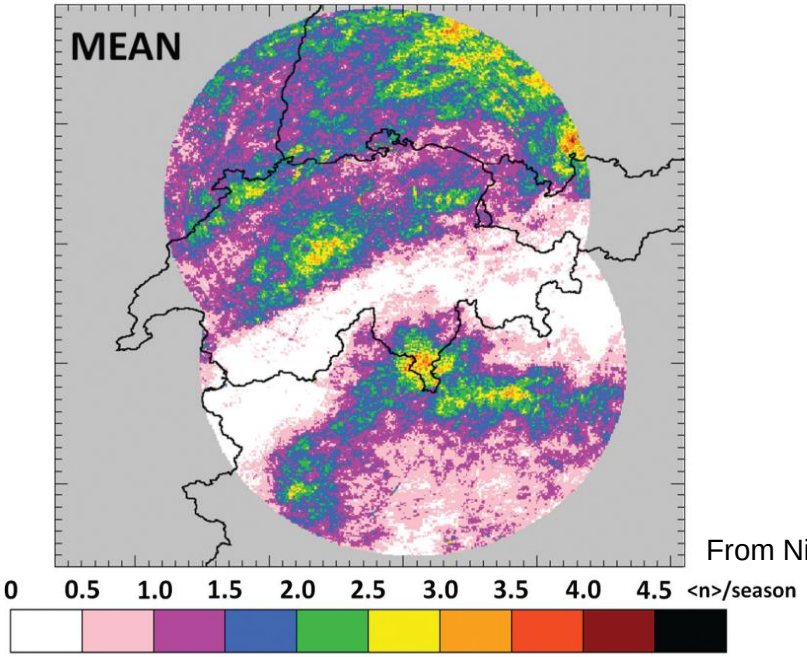
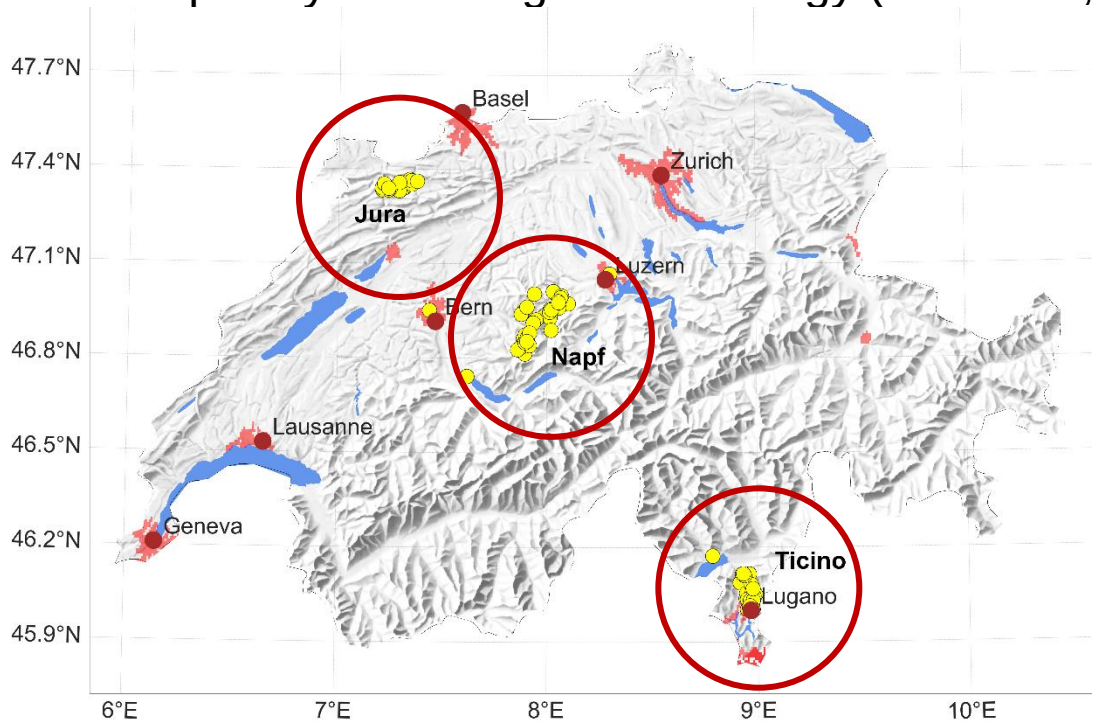
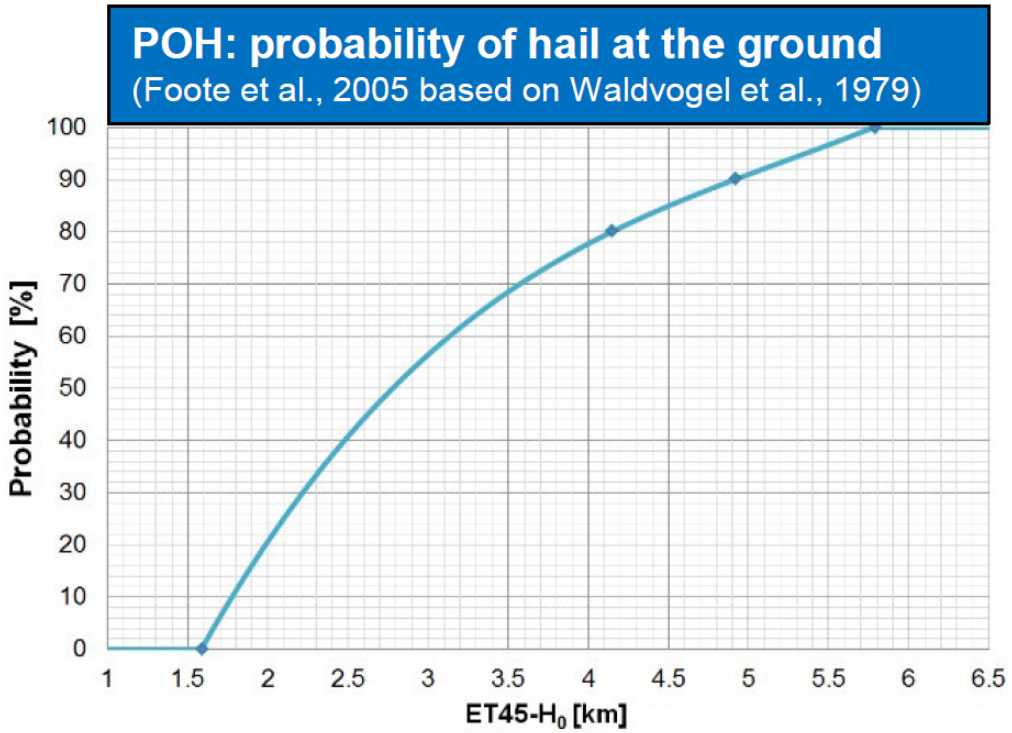
- Since 2002 – **Radar-based hail products**: POH, MESHS – 5 min / 1km resolution; source: composite 5 MCH radars (ECHOTOP) + COSMO 0°C isotherm
- Since 05.2015 - **Crowdsourced reports**: users of Meteoswiss application reports hail size in, smartphone location and time, reports are filtered to keep only “plausible” hail (see Barras et al. 2019 for details)
- Since 06.2018 - **Automatic hail sensor network** : 80 sensors installed between 06.2018 and 07.2020 in 3 regions (Jura, Napf, Ticino) where hail is to be expected frequently according to climatology (Nisi et al., 2016, 2018) -> Project Schweizer Hagelmessnetz

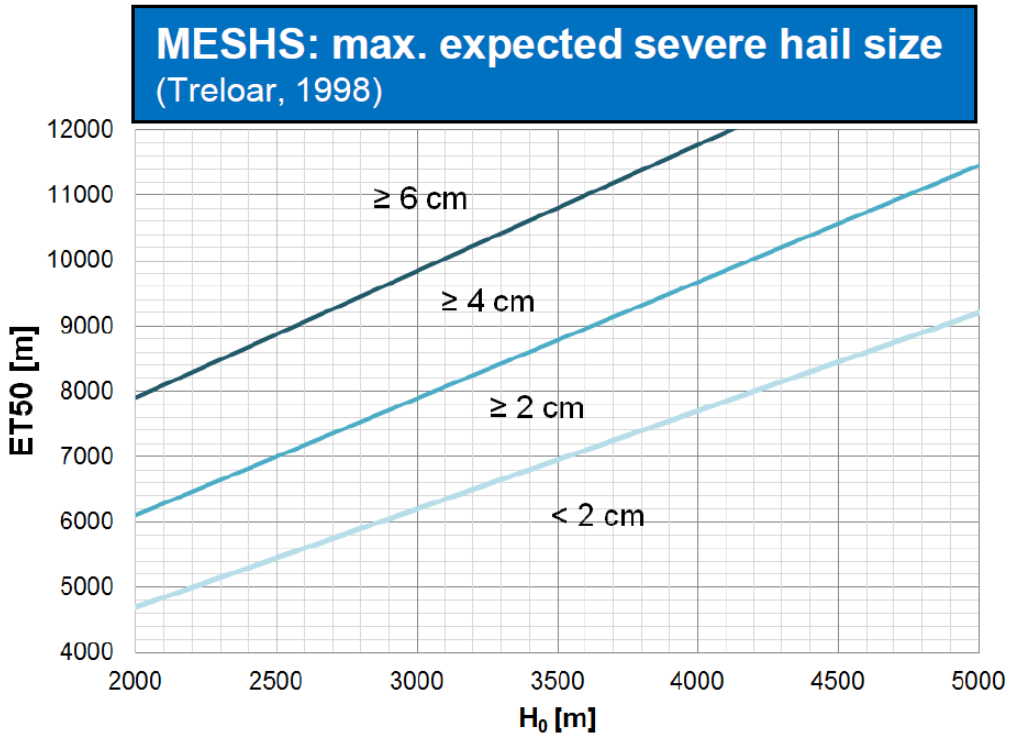


From Nisi et al., 2016



POH and MESHS radar-based products





- POH and MESHS both depend on height of the **0°C-isotherm** (H_0, from NWP model) and specific **EchoTop heights** (from radar)
- Data resolution: **5 min**, **1 km²**

source: MeteoSwiss (Katharina Schroeer)

Project “Schweizer Hagelmessnetz”

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- The purpose of the Swiss Hail Network is to record for the first time the impact energy, grain size distribution and precise time of hailstorms
- Financed by Swiss Mobiliar, sensor developed by inNET Monitoring AG based on an idea of Prof. Martin Löffler-Mang from htw Saarbrücken.
- The hail sensor consists of a Makrolon (thermoplastic) disc with a diameter of 50cm. The Makrolon disc begins to oscillate upon the impact of a hailstone. The oscillations are recorded by a highly sensitive microphone.
- Time resolution: 200ms

Mobiliar / Sascha Moetsch

© Manu Friederich

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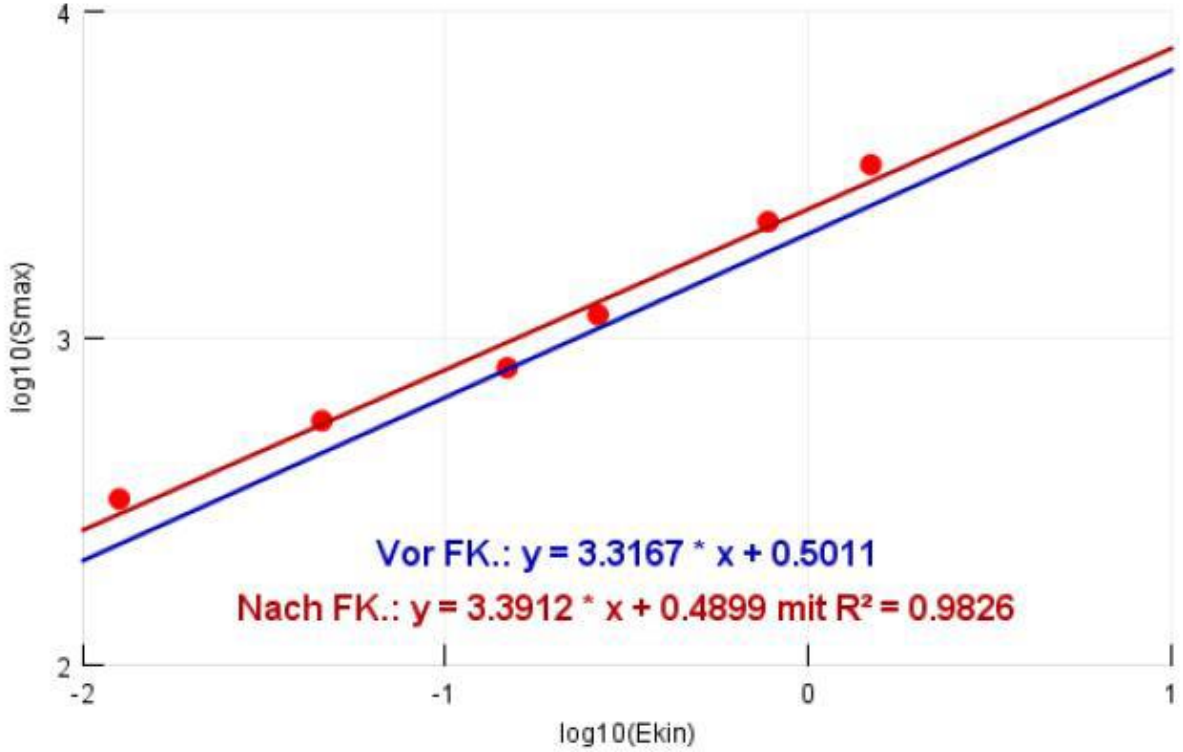
Hailstone diameter measurements

- Raw “digits” from sensor -> (calibration) hail kinetic energy -> (formula) hailstone diameter
- Calibration by the manufacturer under laboratory conditions before delivery
- Calibration once a year before and / or during the hail season (exposure to weather)



Example of a field calibration using the sensor at the SwissMetNet site in Flühli (FK = field calibration). From inNET Projektdokumentation V2.4 – 21.01.2021

$$d_{hail} = \sqrt[4]{\frac{9*E_{kin}*\rho_{Air}*c_w}{(\rho_{ice})^2*\pi*g}}$$

$$\rho_{Air} = 1{,}2\,\frac{kg}{m^3}\,,\quad c_w = 0{,}5\,,\quad \rho_{ice} = 870\ kg/m^3$$

For spherical hailstones with constant drag coefficient c_w. Microphysics of Clouds and Precipitation. 2nd ed. Springer, 954 pp

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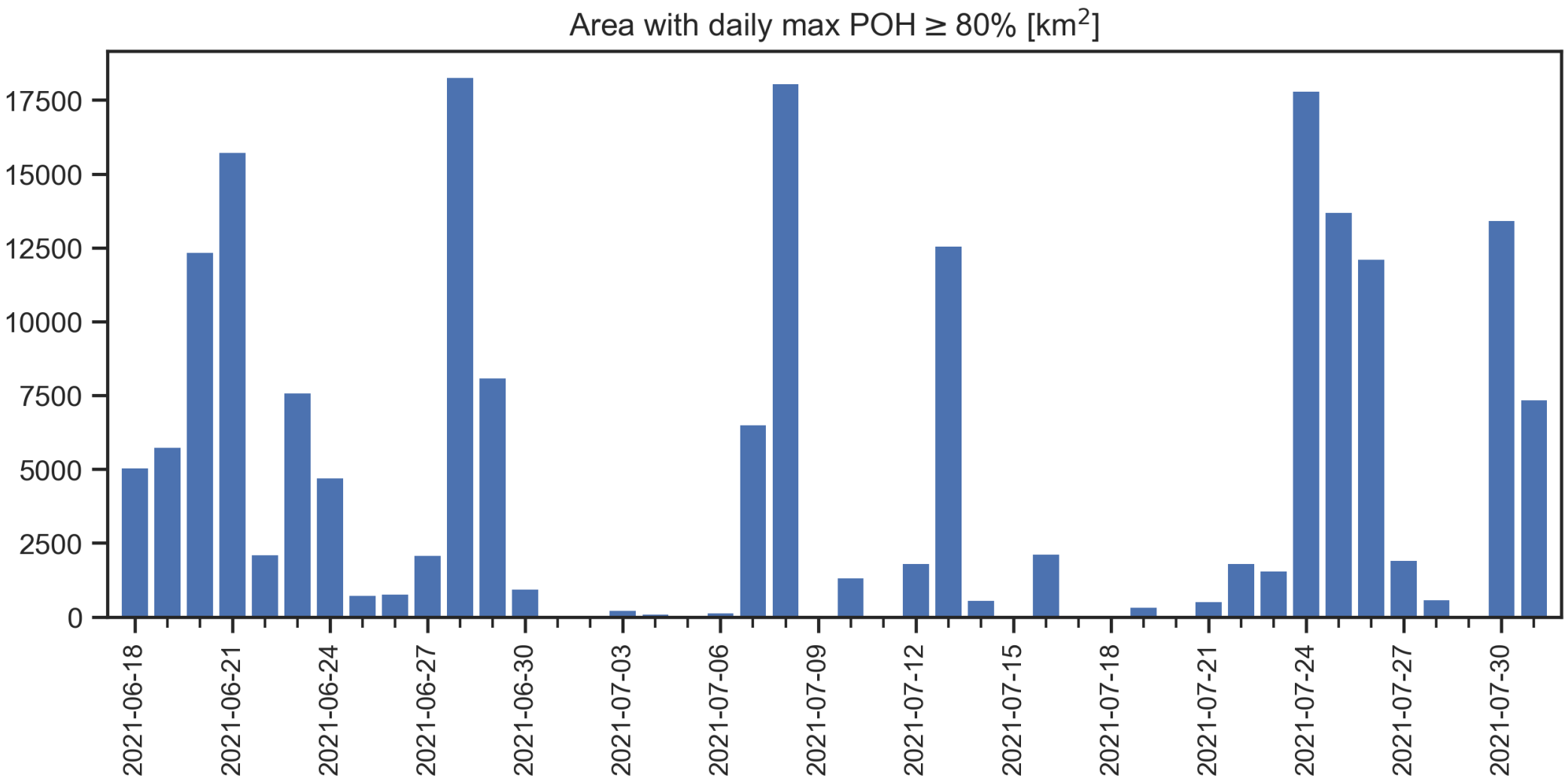
Hail measurements from 18 June to 31 July 2021

POH from 18.06.2021 to 31.07.2021



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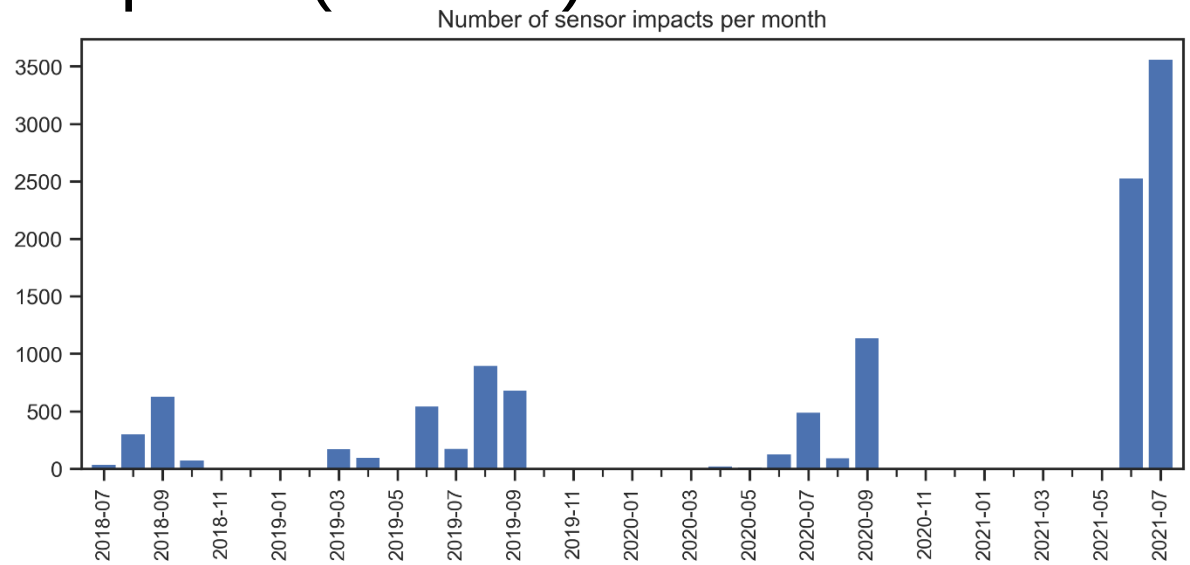
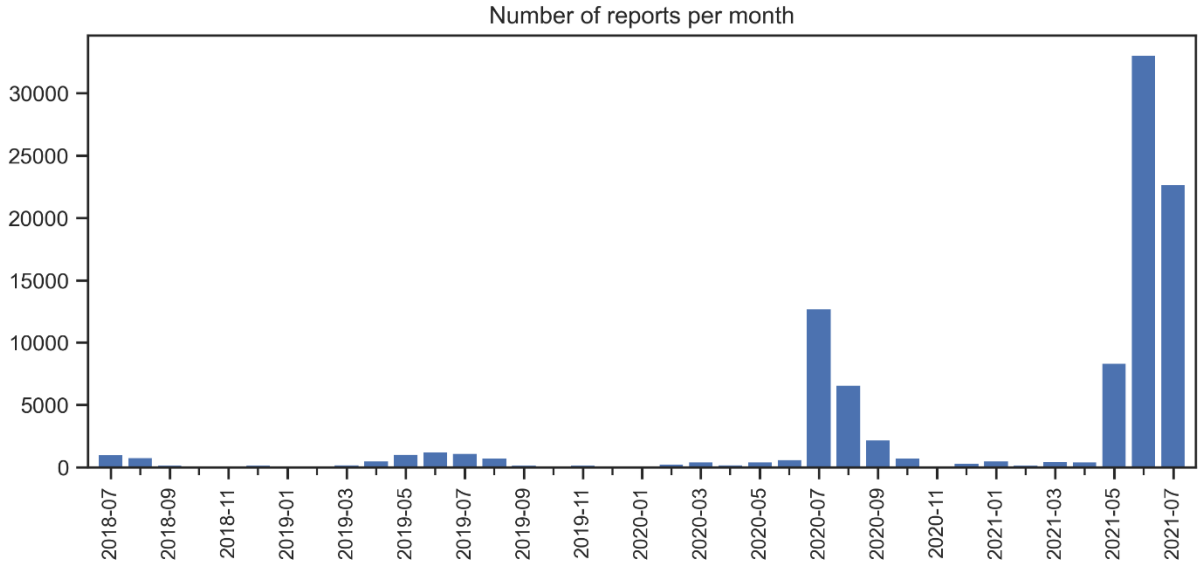
Monthly sensor measurements (top) and crowdsourced reports (bottom)

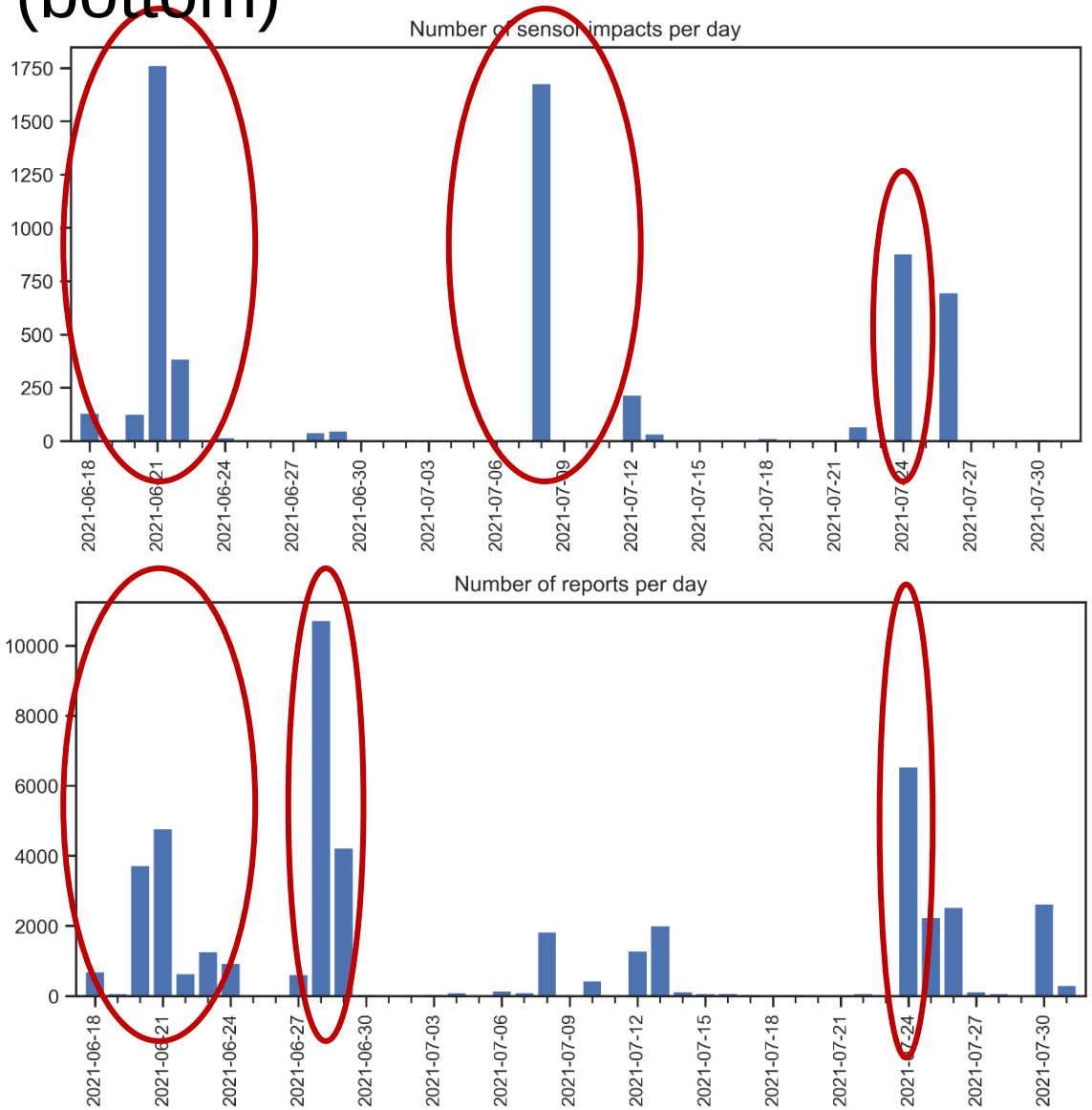




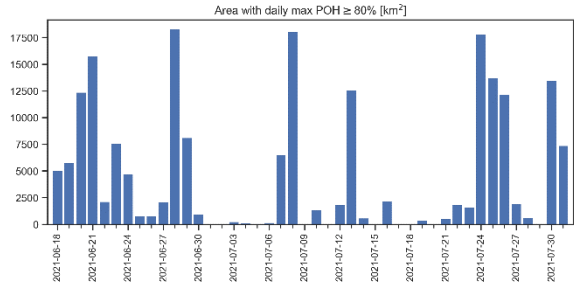
- **Around 6000 impacts in June and July 2021**
- Sensors with at least 5 daily impacts
- Network is fully operational since March 2020
- **53% of impacts**

- **Around 50’000 reports in June and July 2021**
- Filtered, without “no hail”, reports
- Function “concealed” from September 2017 to July 2020
- **50% of reports**

Daily sensor measurements (top) and crowdsourced reports (bottom)



- Sensors are in 3 small areas + their surface is 0.2 m^2
- Reports depend on population density
- Amount of data strongly dependent on storm path/location



Focus on days with most data:
(20.06.2021)
(21.06.2021)
28.06.2021
08.07.2021
(24.07.2021)

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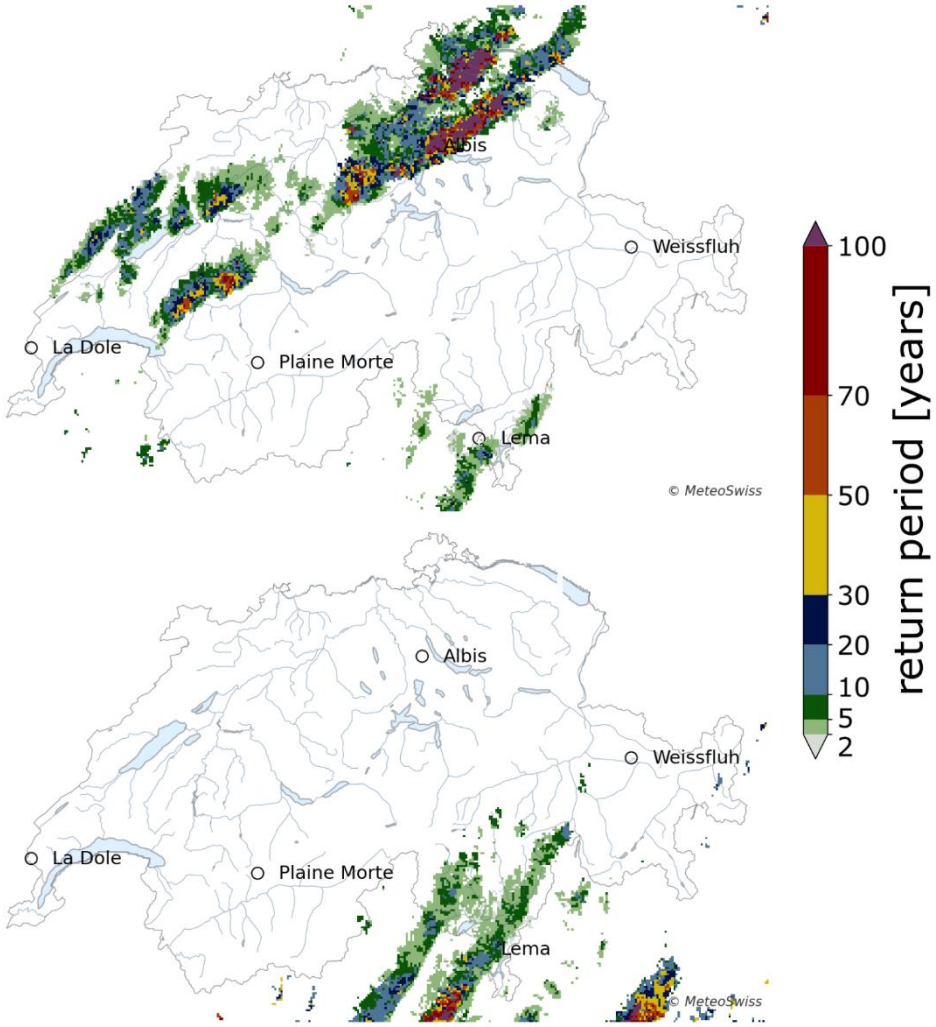
Climatology

Climatology

Table 1: Daily maximum MESHS and areas of the five most intense 2021 hail events for Switzerland (CH), North of the Alps (NoA) and South of the Alps (SoA). The rank is given in brackets, top-ten ranks are shown in bold. Ranks are given relative to all 3660 potential hail days of the hail seasons 1 Apr - 30 Sep 2002-2021, of which 645 had hail areas $\geq$100 km^2.

	region	20.06.2021	21.06.2021	**28.06.2021**	**08.07.2021**	24.07.2021
a) Maximum MESHS (Maximum Expected Severe Hail Stone Size) in event [cm]						
	CH	8.2	7.2	9.2	6.3	6.9
	NoA	8.2	7.2	9.2	2.3	6.9
	SoA	6.8	3.7	7.4	8.8	8.1
b) Event area [thous. km^2]						
hail likely (POH$\geq$80)	CH	4.4 (34)	3.8 (43)	**8.8 (2)**	2.5 (83)	**8.0 (5)**
	NoA	9.9 (26)	13.9 (11)	13.7 (12)	0.06 (951)	1.1 (19)
	SoA	1.3 (270)	0.4 (598)	2.4 (134)	**15.4 (1)**	3.4 (76)
severe hail (MESHS$\geq$4 cm)	CH	**19 (7)**	1.0 (23)	**4.4 (1)**	0.5 (68)	1.0 (25)
	NoA	2.7 (18)	3.4 (11)	**5.9 (2)**	0 (1593)	1.1 (66)
	SoA	0.14 (297)	0 (1557)	0.4 (136)	**4.8 (1)**	1.2 (34)
extreme hail (MESHS$\geq$6 cm)	CH	**0.8 (3)**	0.05 (70)	**1.1 (1)**	0.008 (169)	0.07 (57)
	NoA	**0.9 (6)**	0.16 (67)	**1.5 (2)**	0 (1337)	0.06 (121)
	SoA	0.02 (238)	0 (1368)	0.03 (219)	**1.1 (1)**	0.3 (22)



Local return period estimates for 28 June (top) and 8 July 2021 (bottom). Estimates refer to the frequency of expected annual maximum MESHS per radar pixel (1 km^2) and are based on 3000 synthetic years calculated with an environmentally constrained stochastic resampling approach (Schroeer et al., 2022)

Contribution from Katharina Schroeer

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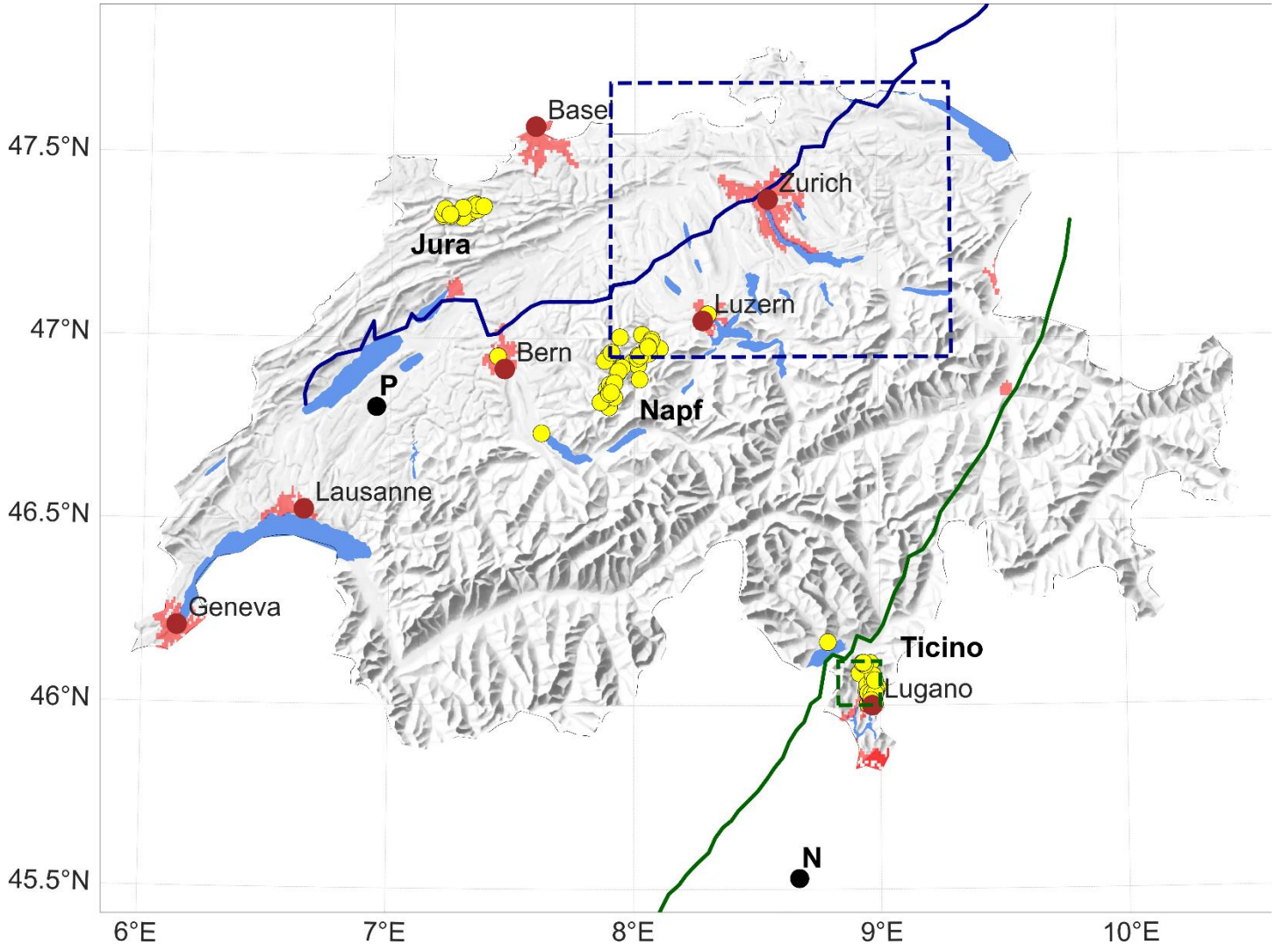
Weather description of June 28 and July 8 2021

All the ingredients for severe convection (instability, shear, high CAPE, and high moisture levels) were present over Switzerland on both days, generating several storm cells.

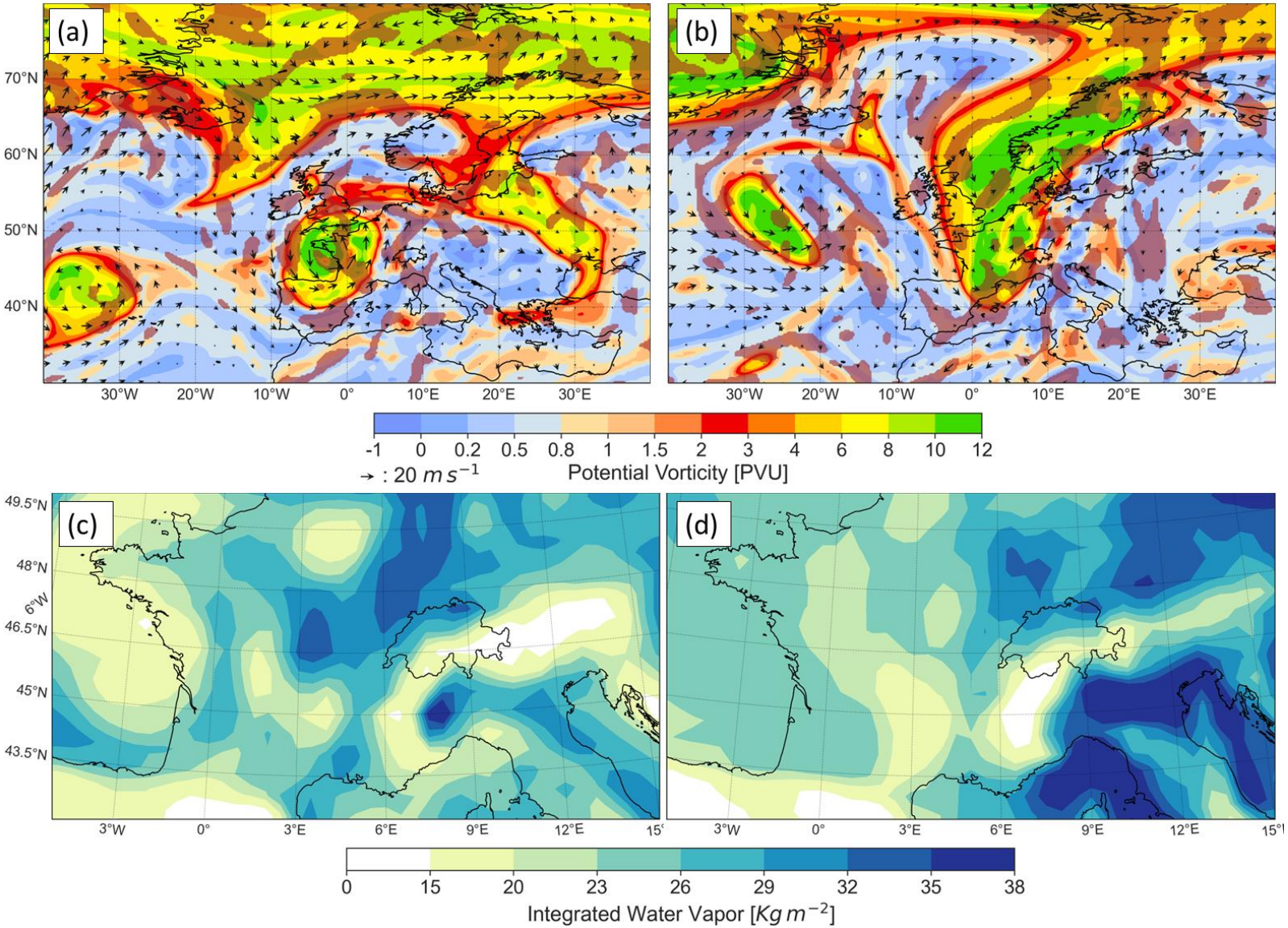
Main storm tracks



Map of Switzerland. Red patches show urban areas; yellow dots denote automatic hail sensor locations in the three hail-prone regions (Jura, Napf, Ticino); **the blue and green tracks show the path of the centroid of the longest living storms of 28 June and 8 July 2021**, respectively, as derived from radar observations; locations of the Payerne (P) and the Novara Cameri (N) soundings displayed are also shown.

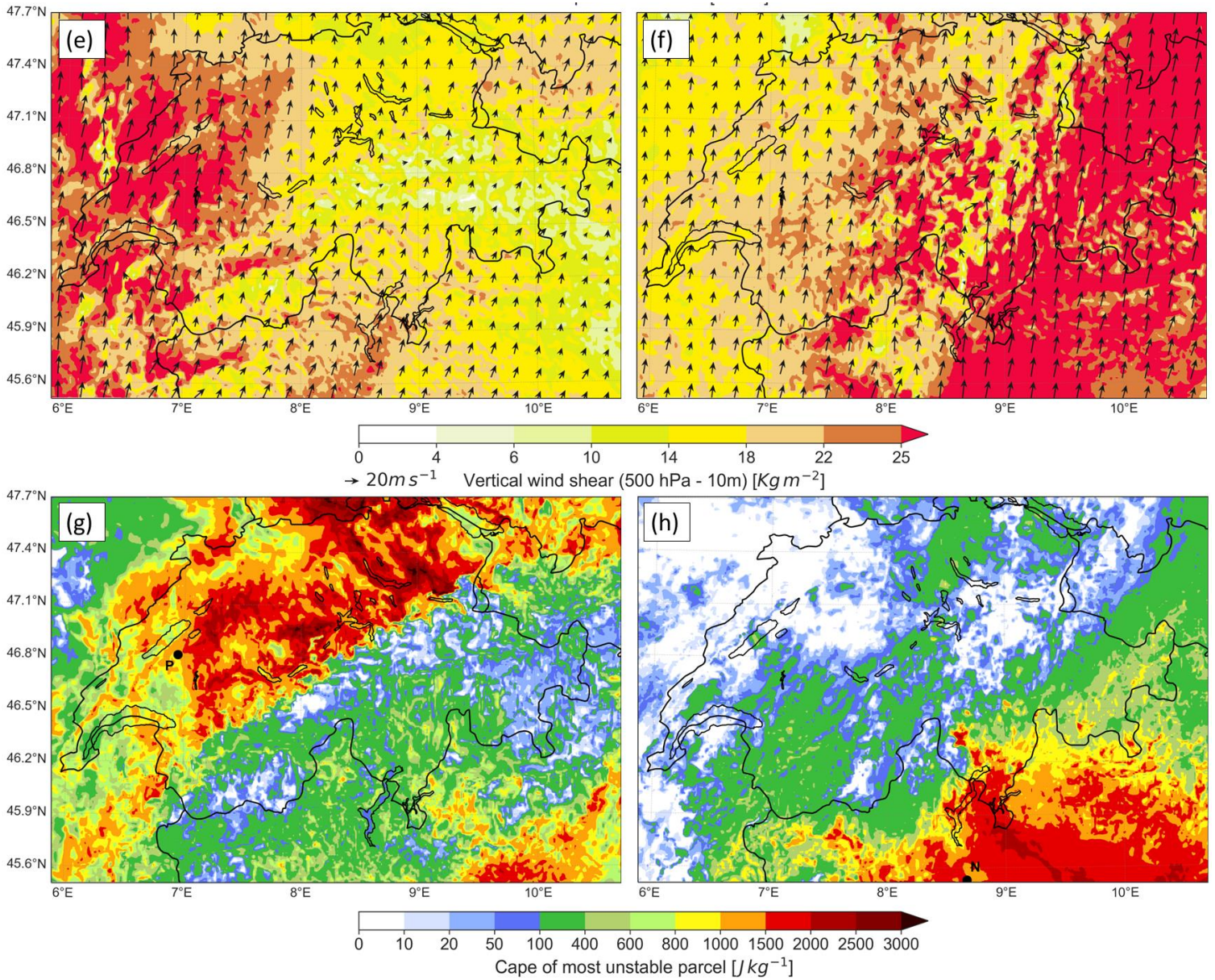
On 28 June, the storms originated in Western Switzerland around 1400 UTC and then moved along the northern flank of the Swiss Alps following southwest to northeast tracks. On 8 July, the storms formed in Northern Italy around 0700 UTC and moved over Southern Switzerland (Ticino) following south to north tracks

Potential Vorticity (PV) and Integrated Water Vapor



(a-b) ERA5 PV on the 330-K isentrope (PV units, color shading), horizontal wind field at the same level in ms-1 (arrows) and Q-vector convergence 5*10 > 10^{-18} m s^{-1} kg^{-1} (brown shading);
(c-d) ERA5 Integrated Water Vapor; on 1200 UTC 28 June 2021 (left) and 0600 UTC 8 July 2021 (right)

Wind Shear and CAPE



(e-f) COSMO2E vertical wind shear (difference between 500-hPa and 10-m wind) magnitude (color shading) and direction (vectors);
(g-h) COSMO2E CAPE of most unstable parcel with location of Payerne (g) and Novara Cameri (h); on 1300 UTC 28 June 2021 (left) and 0800 UTC 8 July 2021 (right).

Soundings

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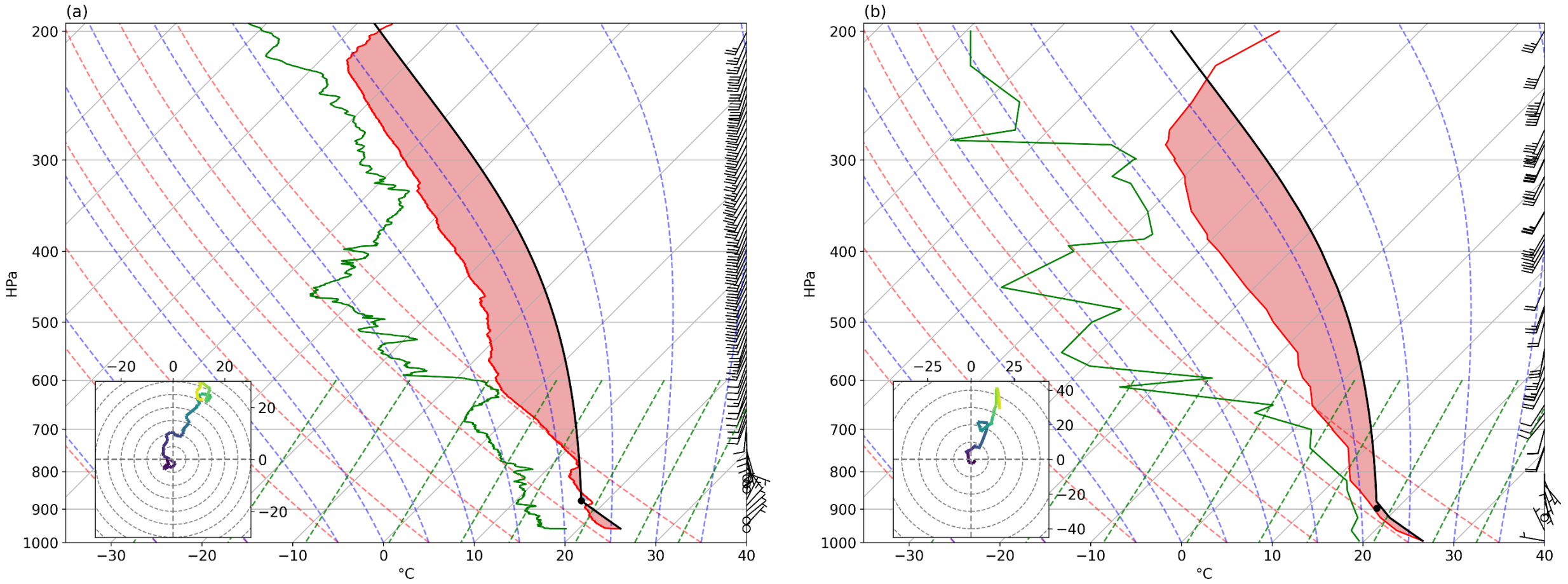

Soundings and hodographs of Payerne (a, left) and Novara Cameri (b, right) stations

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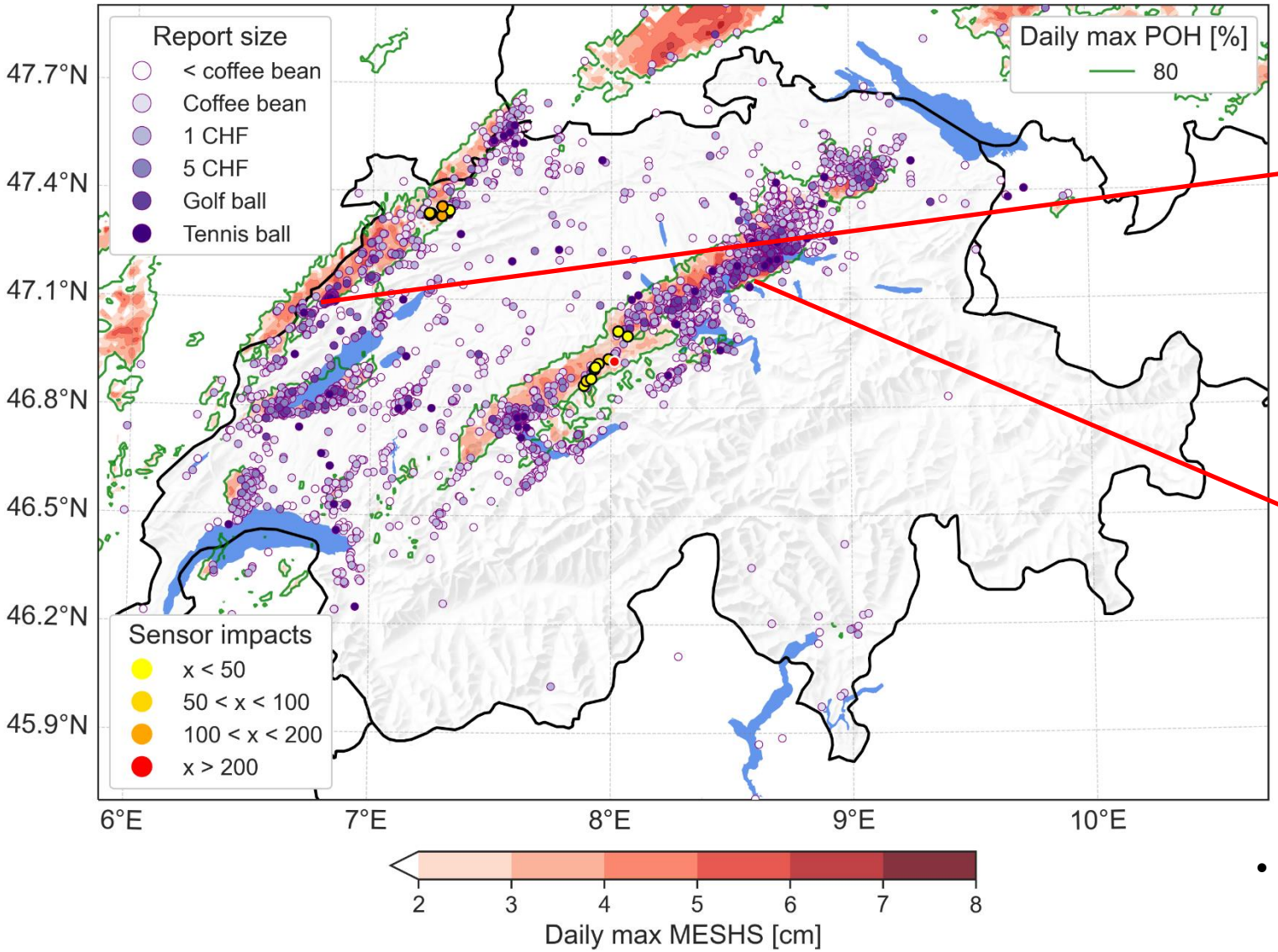
Daily hail footprints

21.06.2021 ~1800 impacts (highest daily number)



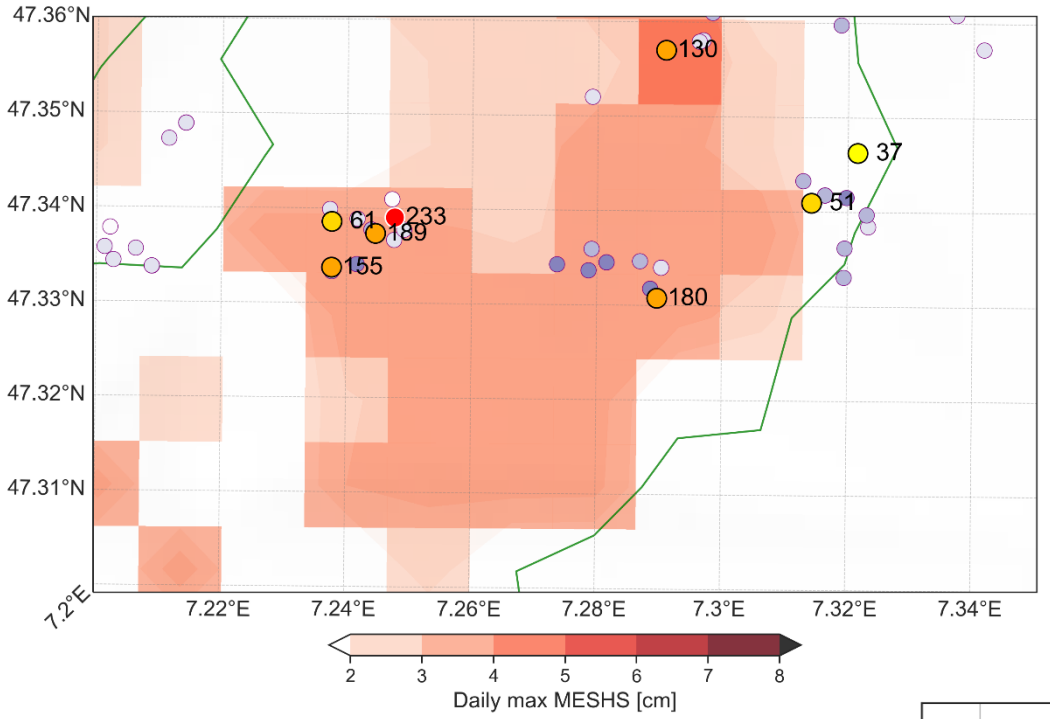
4-5 cm hail in La-Chaux-de-Fonds

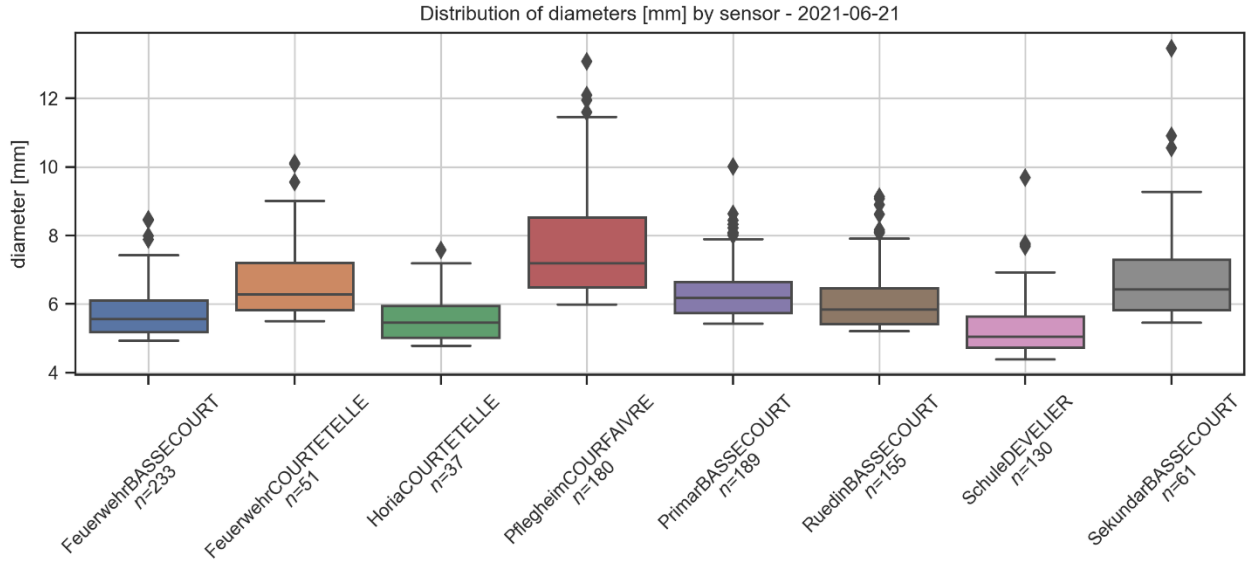
4-5 cm hail in Wadenswil

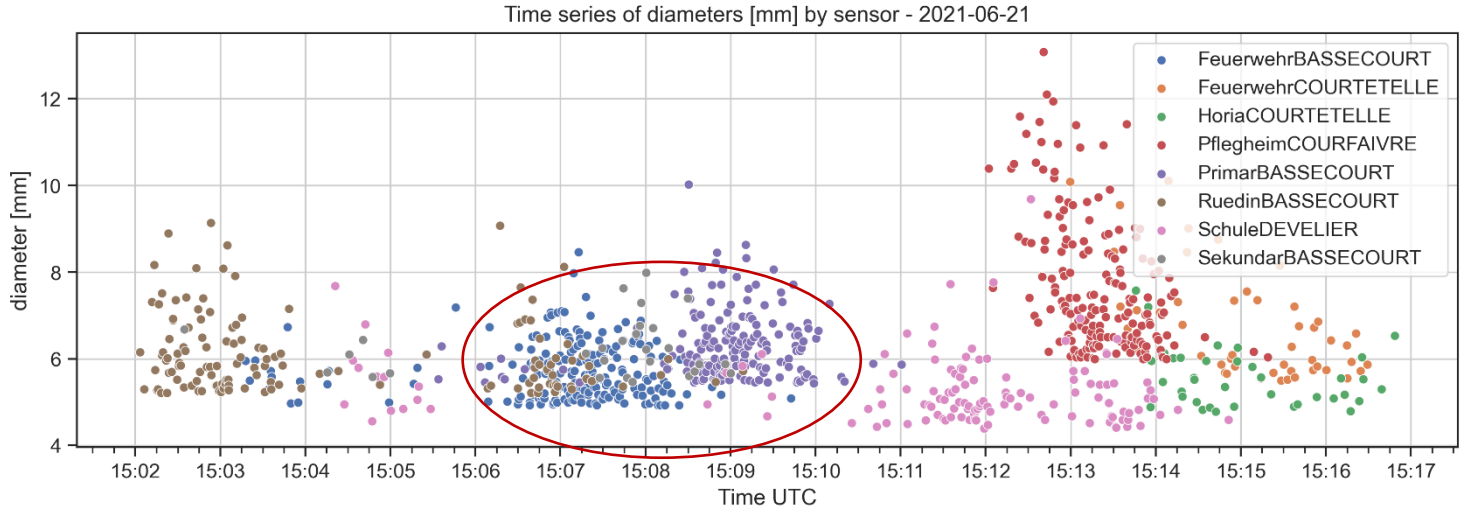
- Around 4700 reports

Picture source: Sturmarchiv Schweiz / www.sturmarchiv.ch, © *Association suisse des risques naturels (top) and © Nine (bottom)*

21.06.2021 – Jura region (sensors with > 30 impacts)

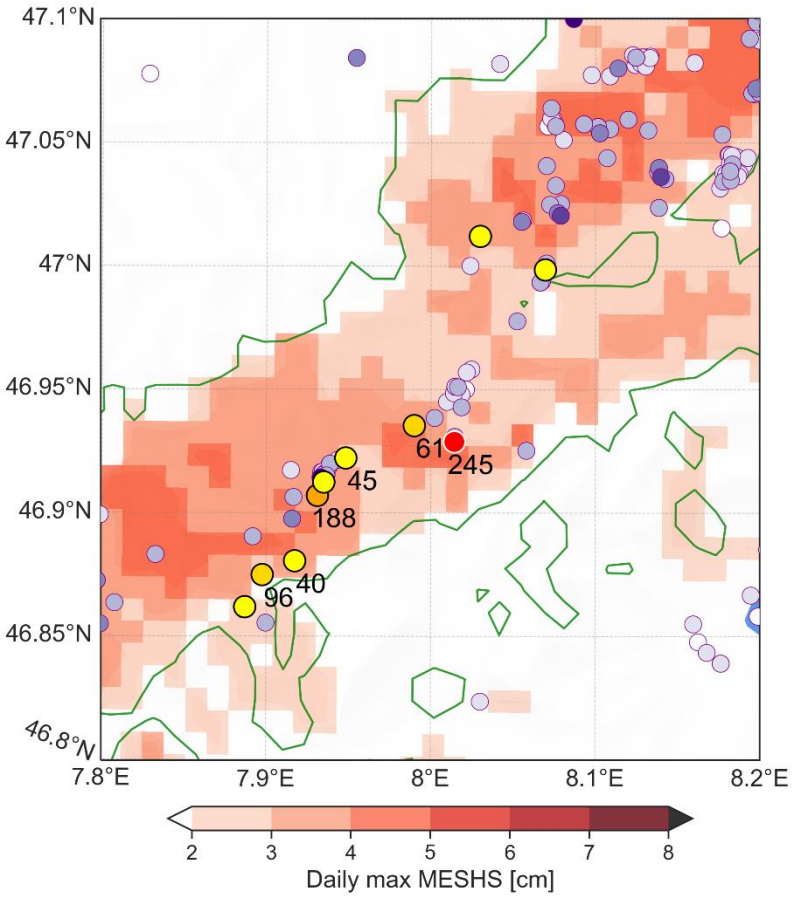


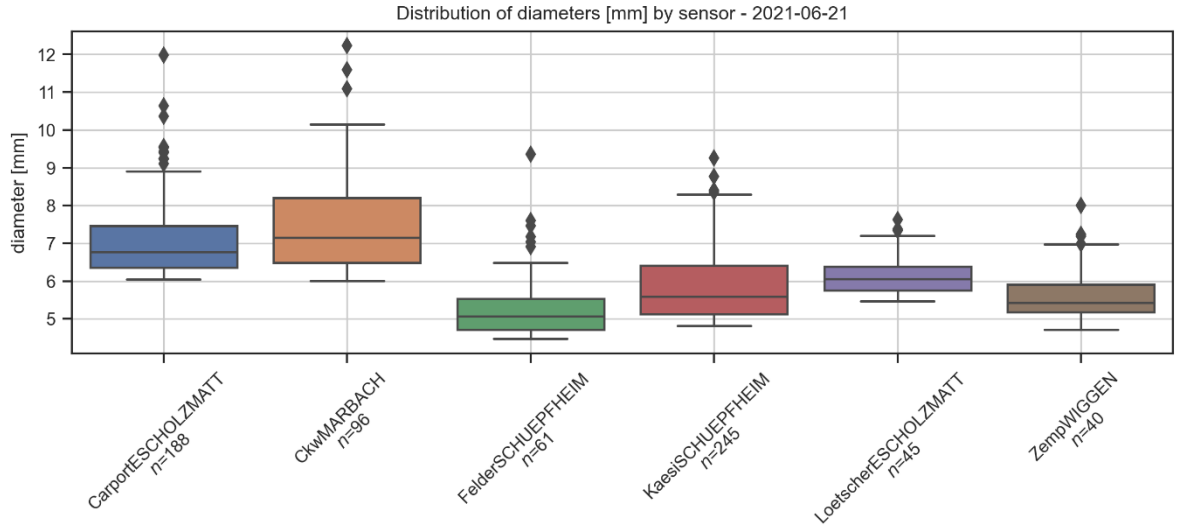


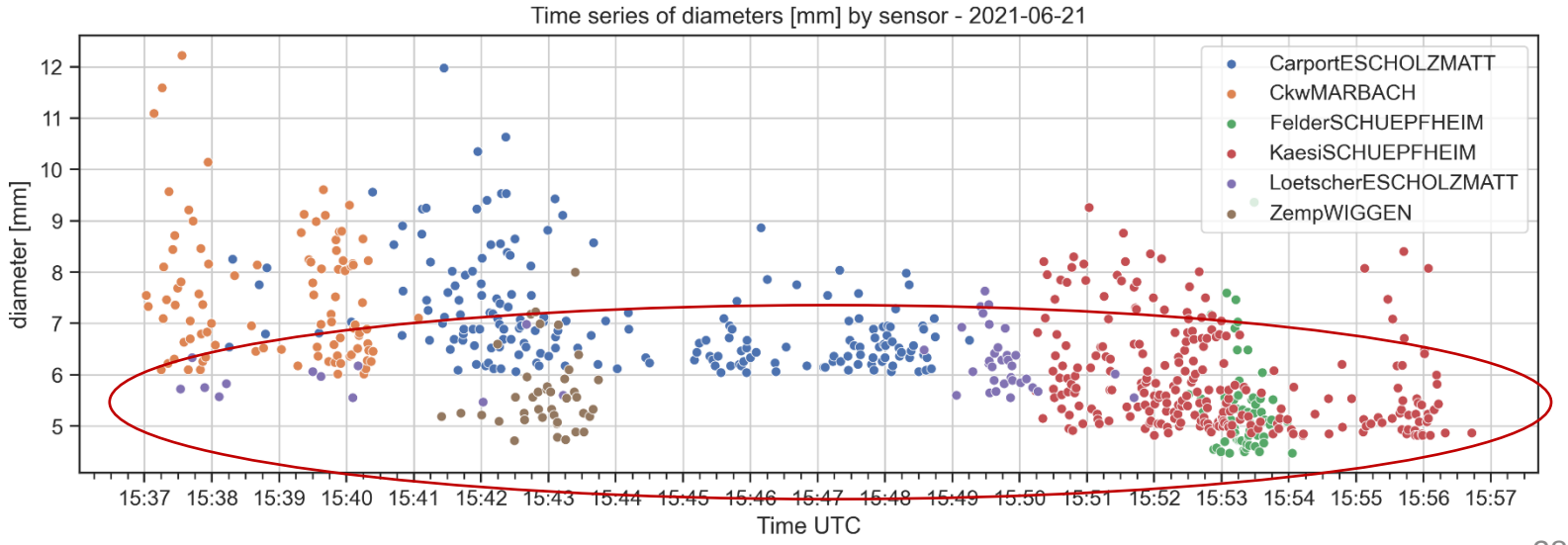


- Some impacts before 1500UTC are not shown
- **different minimum hail size from one sensor to another (1mm) → influence of ambient temperature on calibration**

21.06.2021 – Napf region (sensors with > 30 impacts)

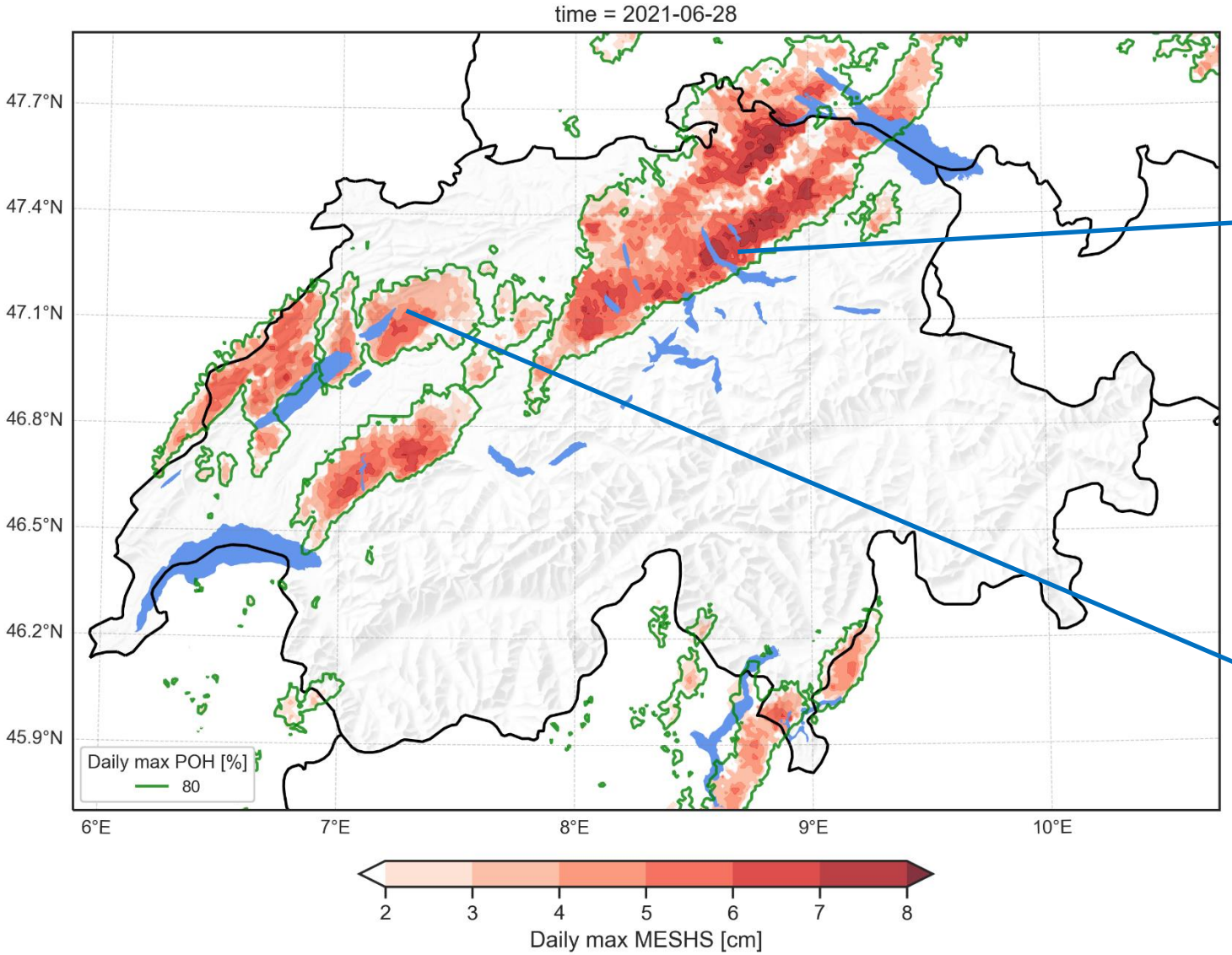






- **different min hail size depending on sensor -> calibration ?**

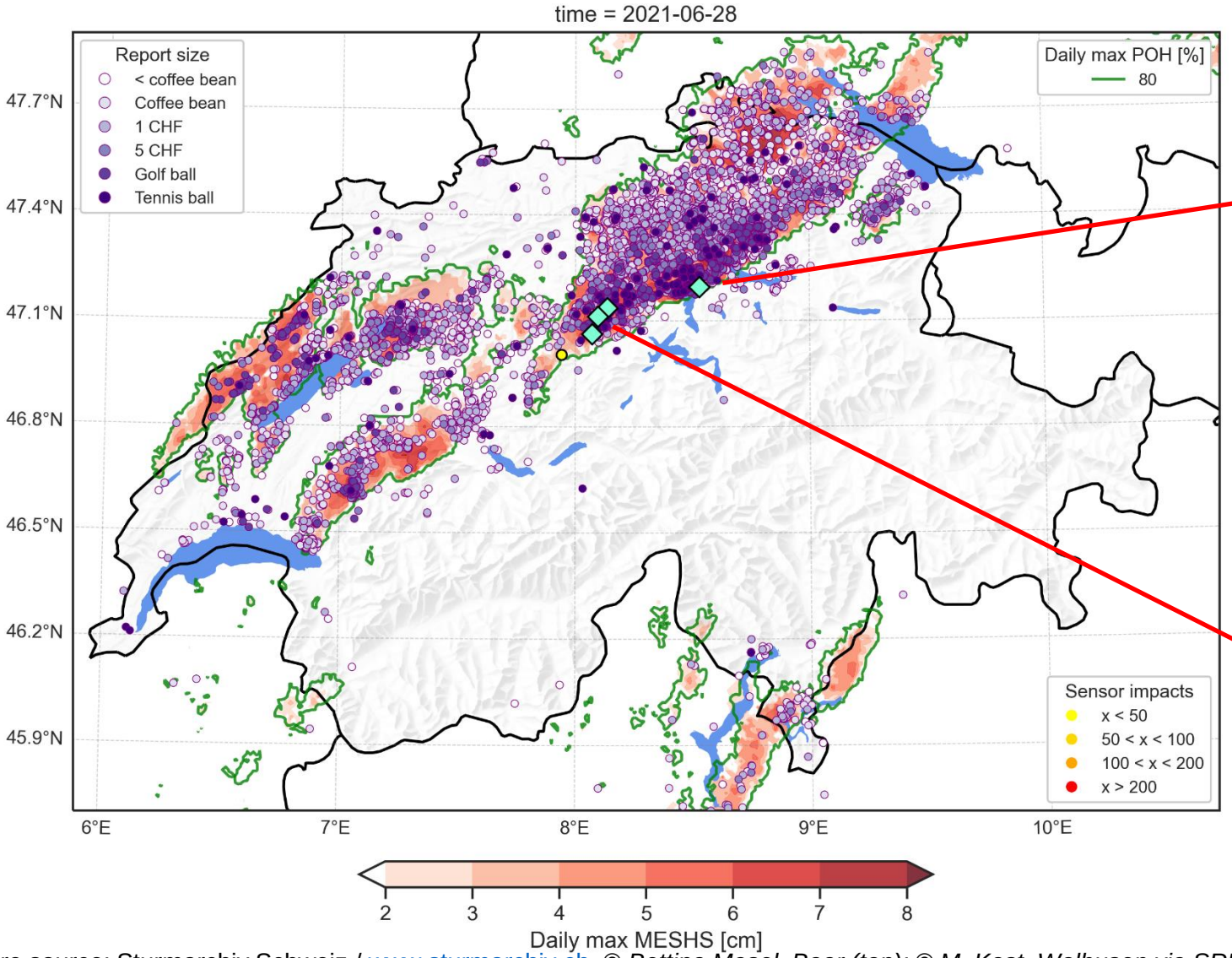
28.06.2021 – Daily Max POH and MESHS



Sturmarchiv Schweiz / www.sturmarchiv.ch, © Cordelia Bommeli

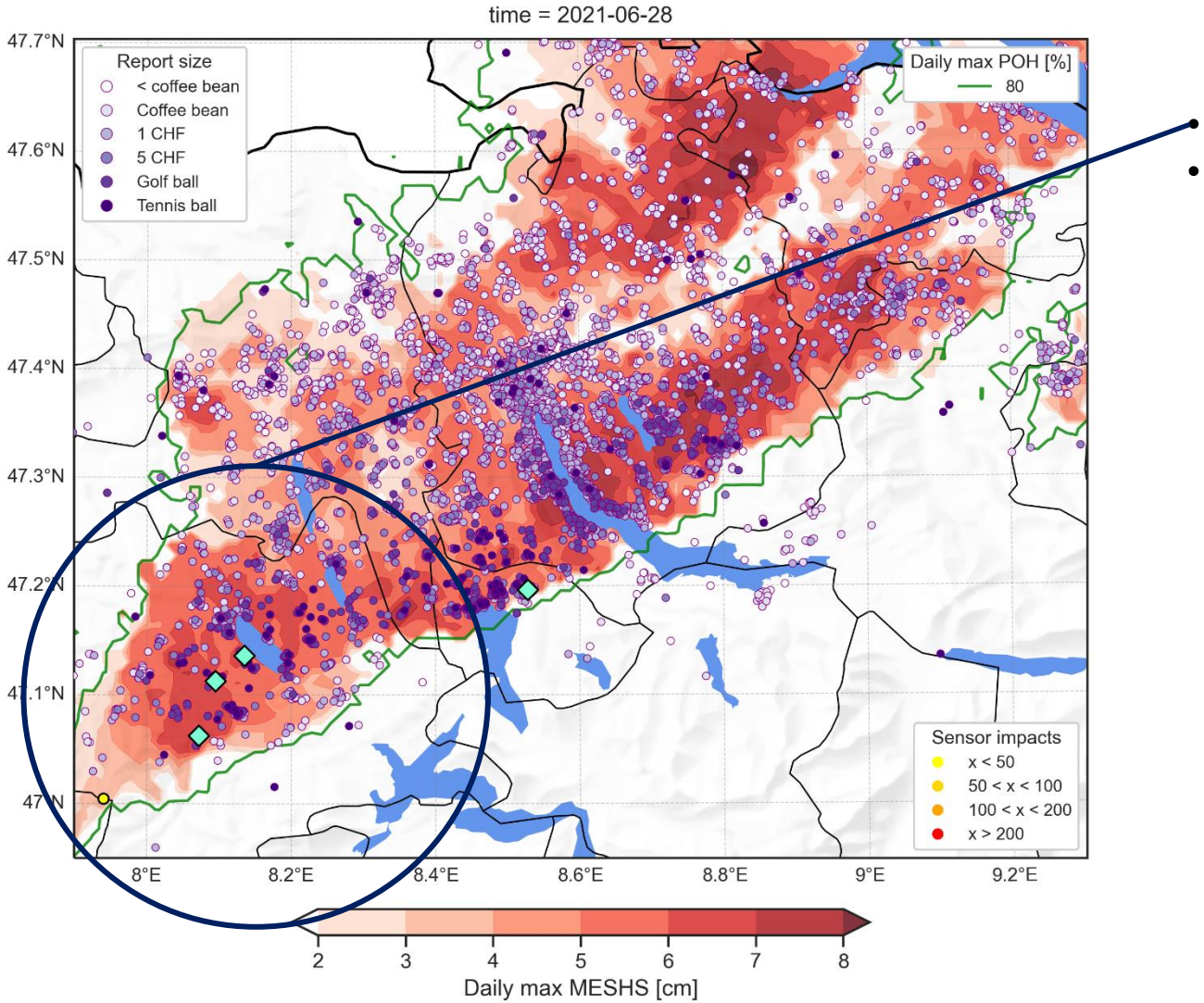
© MeteoSwiss blog, photo by Aude Untersee

28.06.2021 ~ 11’000 reports (highest daily number)



Picture source: Sturmarchiv Schweiz / www.sturmarchiv.ch, *© Bettina Mosel, Baar (top); © M. Kost, Wolhusen via SRF (middle); © Roland Müller, Nottwil via SRF (right); Leserreporter Luzerner Zeitung, Ruswil (bottom)*

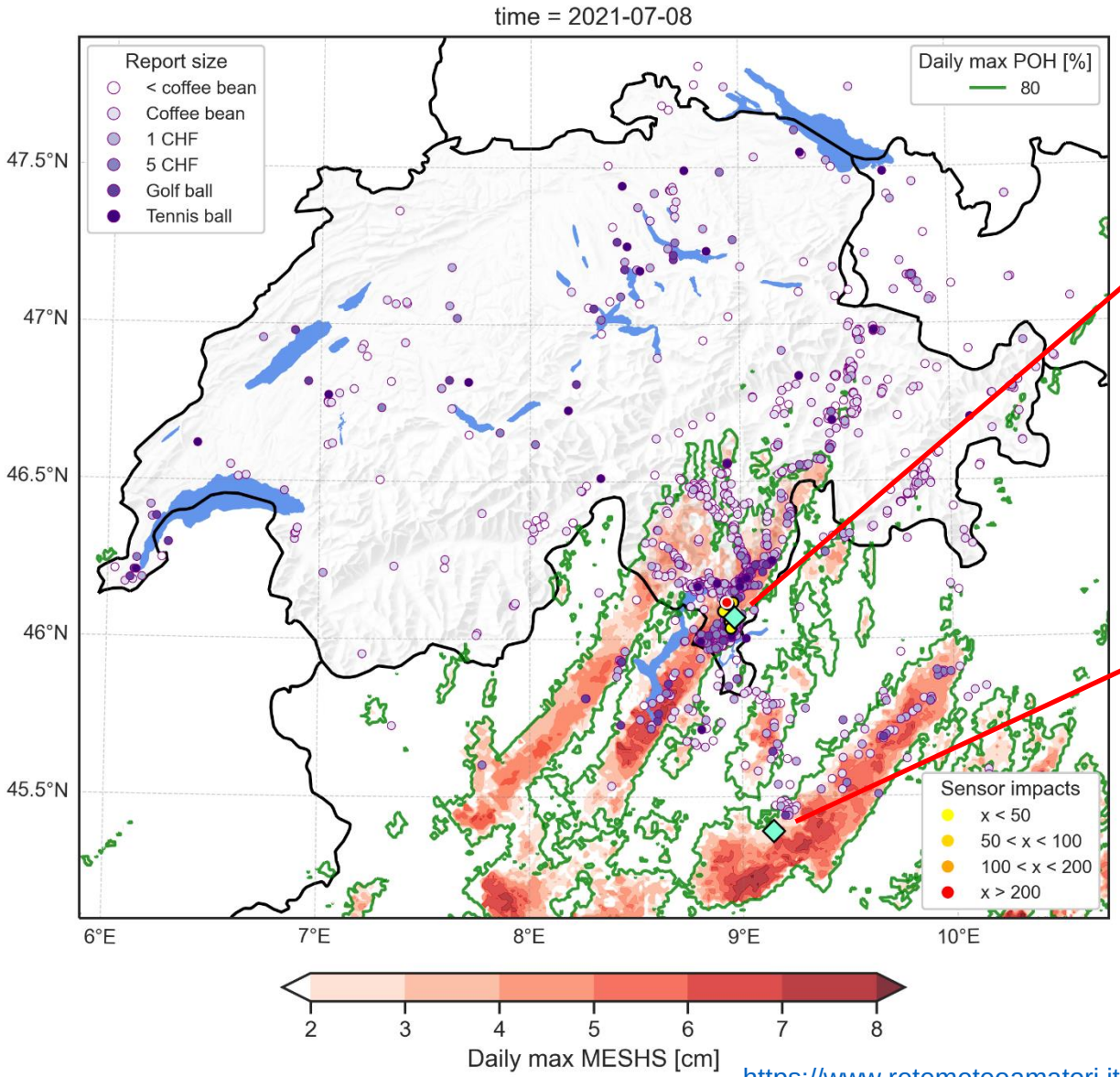
28.06.2021 – Damages due to large hail (7-10cm)



- 12’000 buildings damaged in Kanton Luzern (GVL)
- 11’000 claims (La Mobilière)

Picture source: Sturmarchiv Schweiz / www.sturmarchiv.ch, © *Association suisse des risques naturels (top) and © Nine (bottom)*

08.07.2021 ~1700 impacts

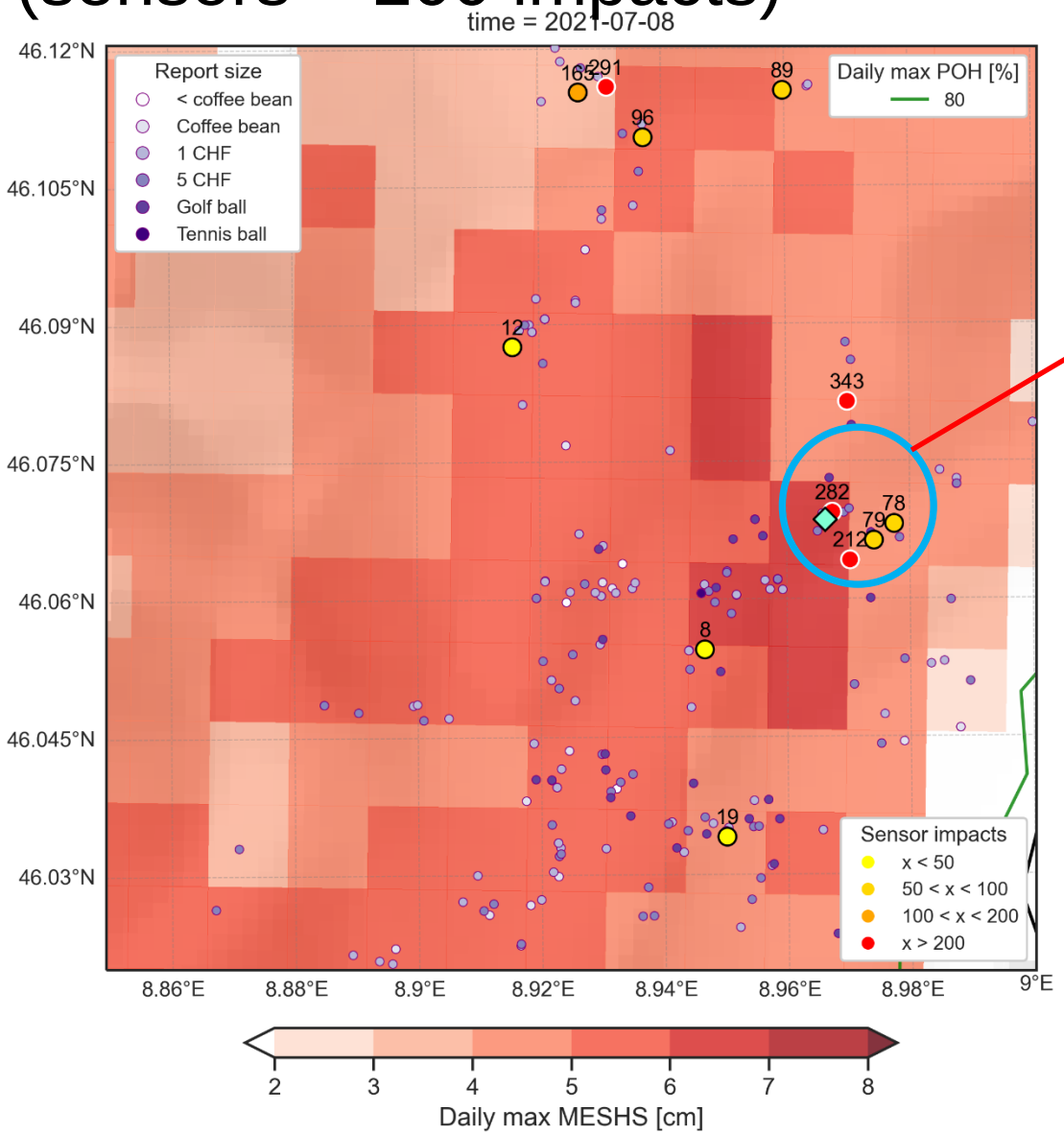


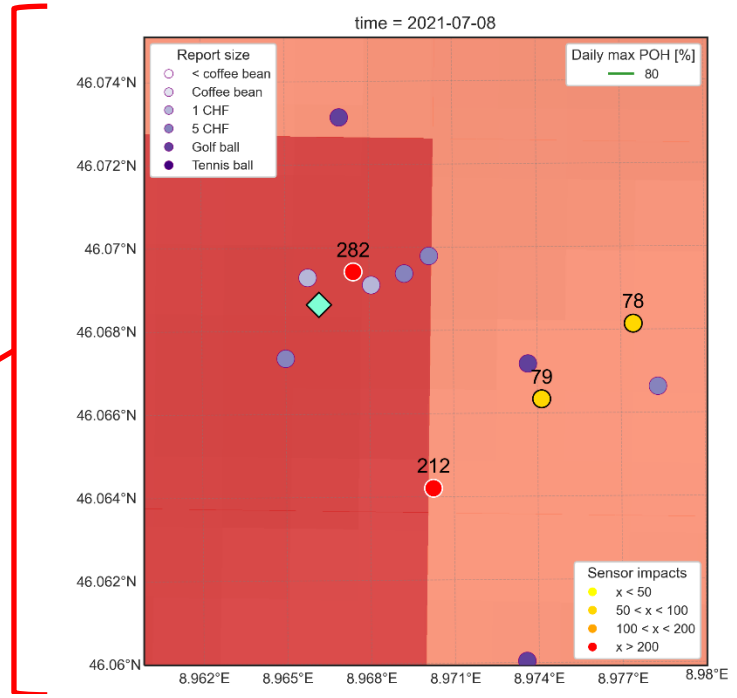
Rozzano, Milano

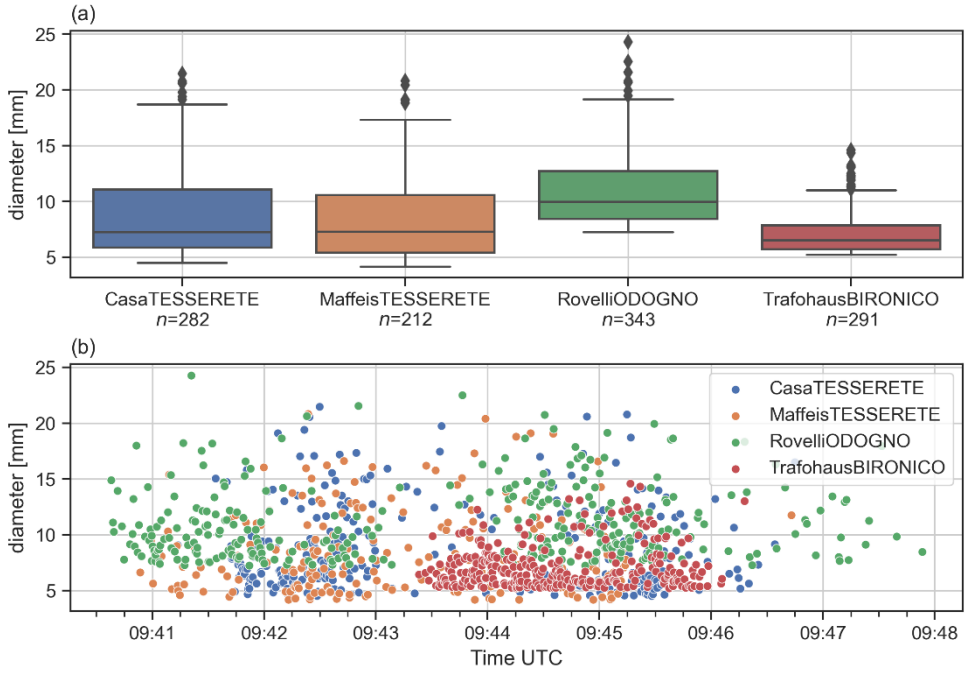
not only Switzerland was affected...

https://www.retemeteoamatori.it/blog/grandine-devastante-a-rozzano-milano-8-luglio-2021/, unidentified author (bottom picture)

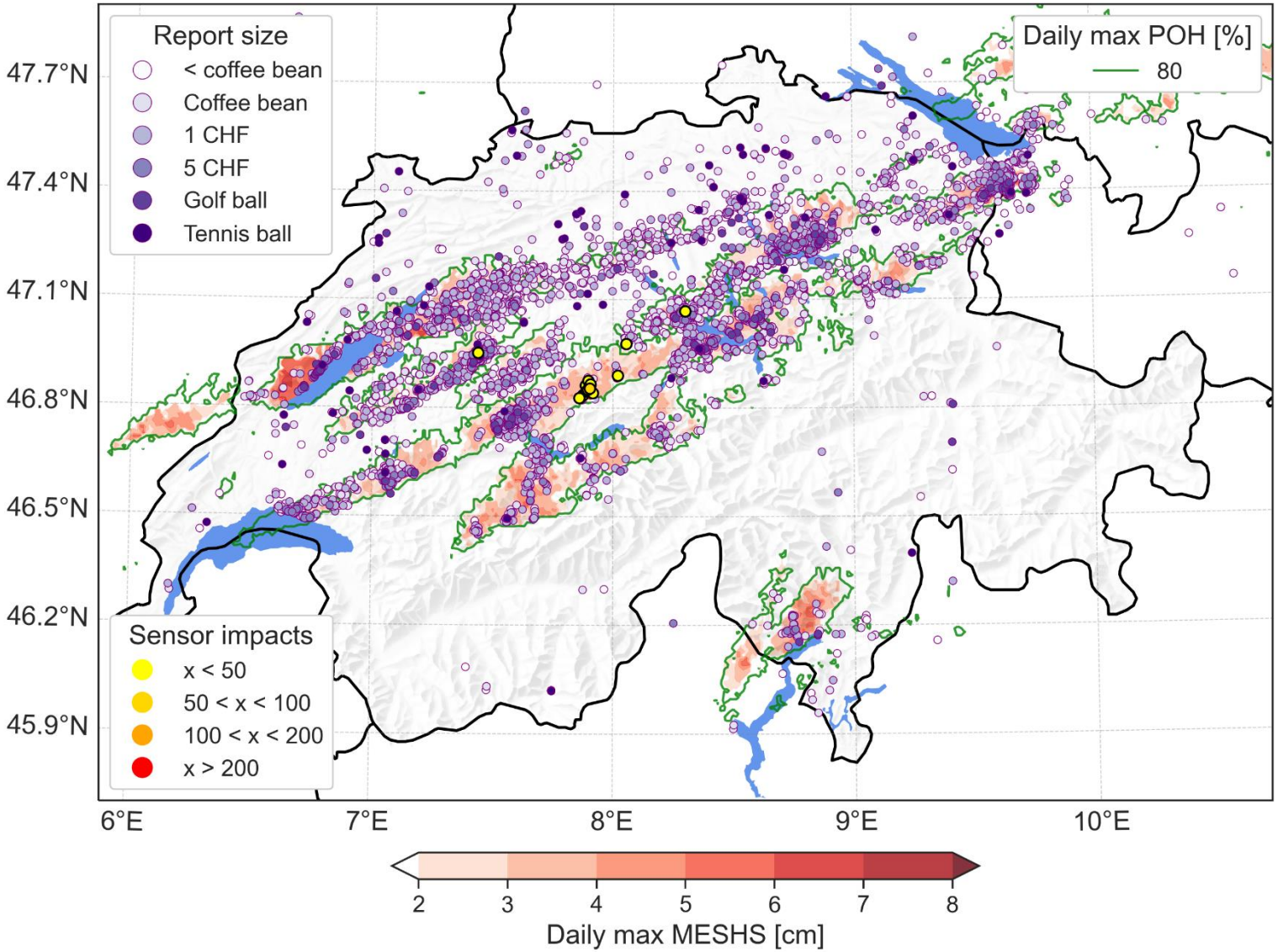
08.07.2021 – Ticino region (sensors > 200 impacts)

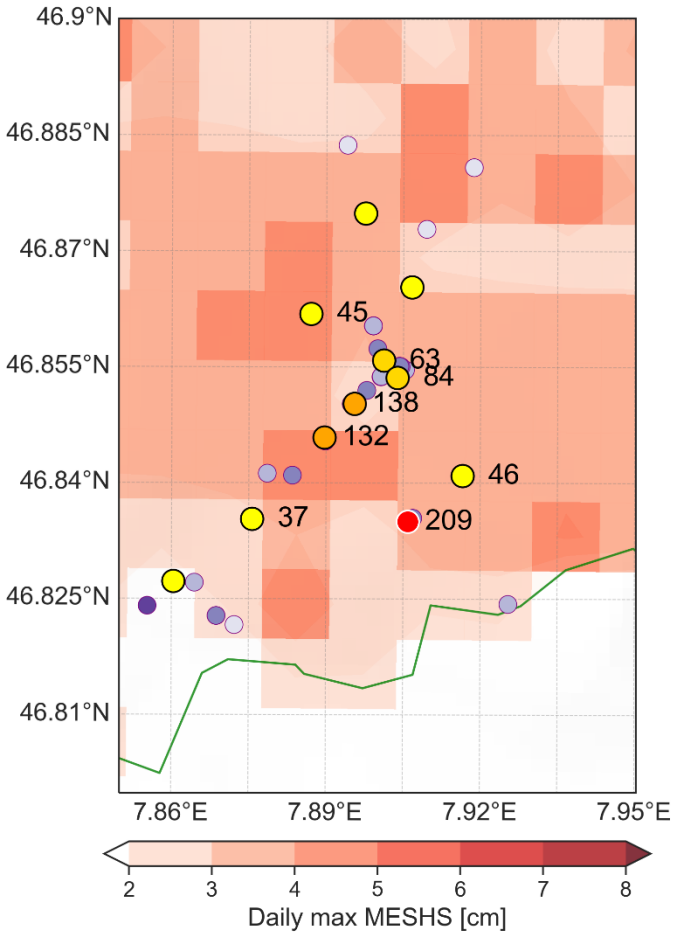






24.07.2021


Report size
< coffee bean
Coffee bean
1 CHF
5 CHF
Golf ball
Tennis ball
Daily max POH [%]
80
Sensor impacts
x < 50
50 < x < 100
100 < x < 200
x > 200
47.7°N
47.4°N
47.1°N
46.8°N
46.5°N
46.2°N
45.9°N
6°E
7°E
8°E
9°E
10°E
2 3 4 5 6 7 8
Daily max MESHS [cm]


46.9°N
46.885°N
46.87°N
46.855°N
46.84°N
46.825°N
46.81°N
45
63
84
138
132
46
37
209
7.86°E
7.89°E
7.92°E
7.95°E
2 3 4 5 6 7 8
Daily max MESHS [cm]

24.07.2021 – Napf region (sensor with > 30 impacts)

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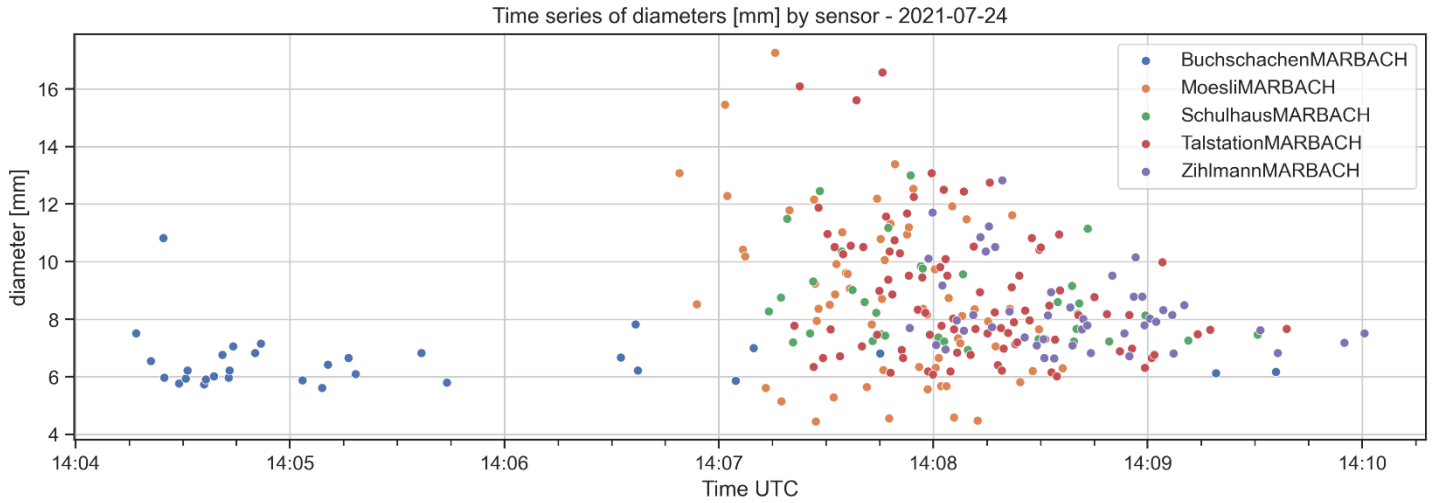
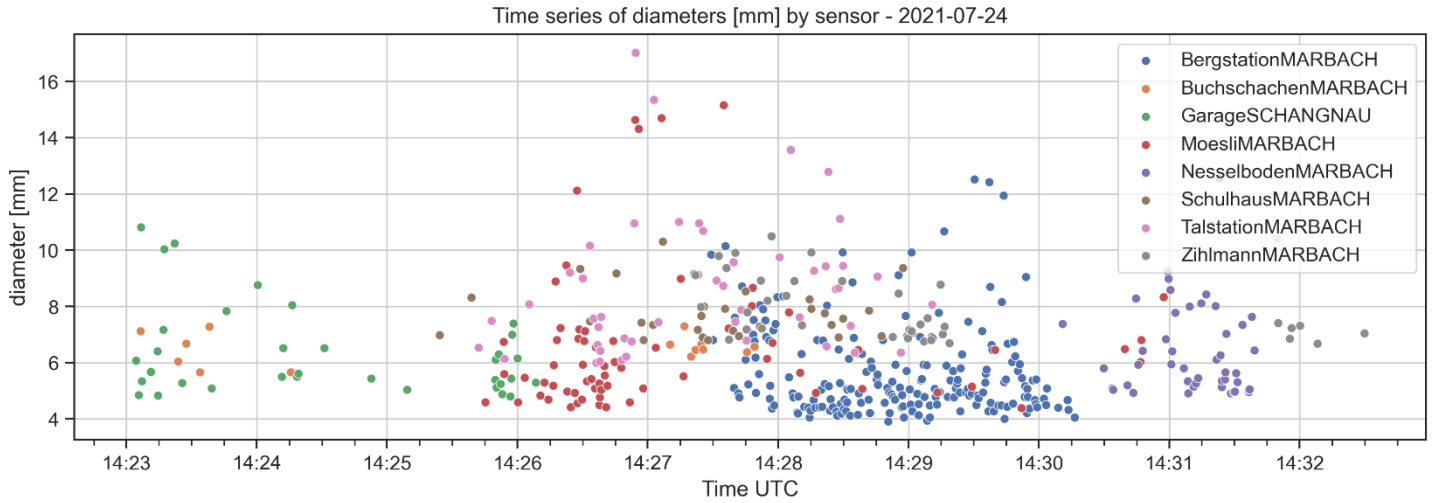
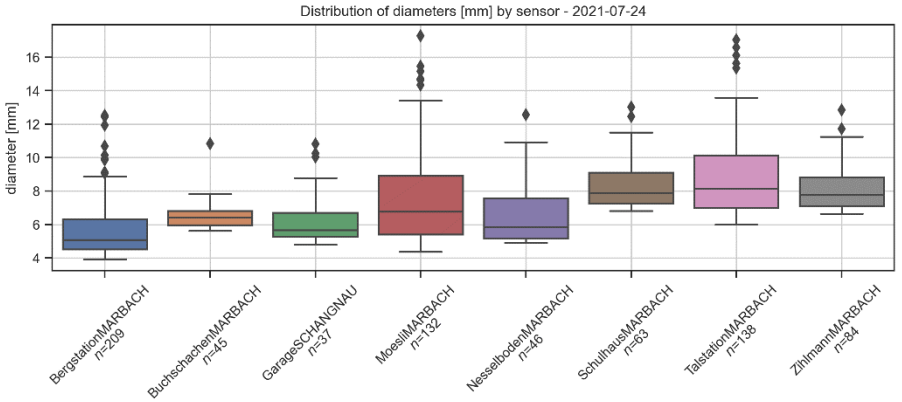
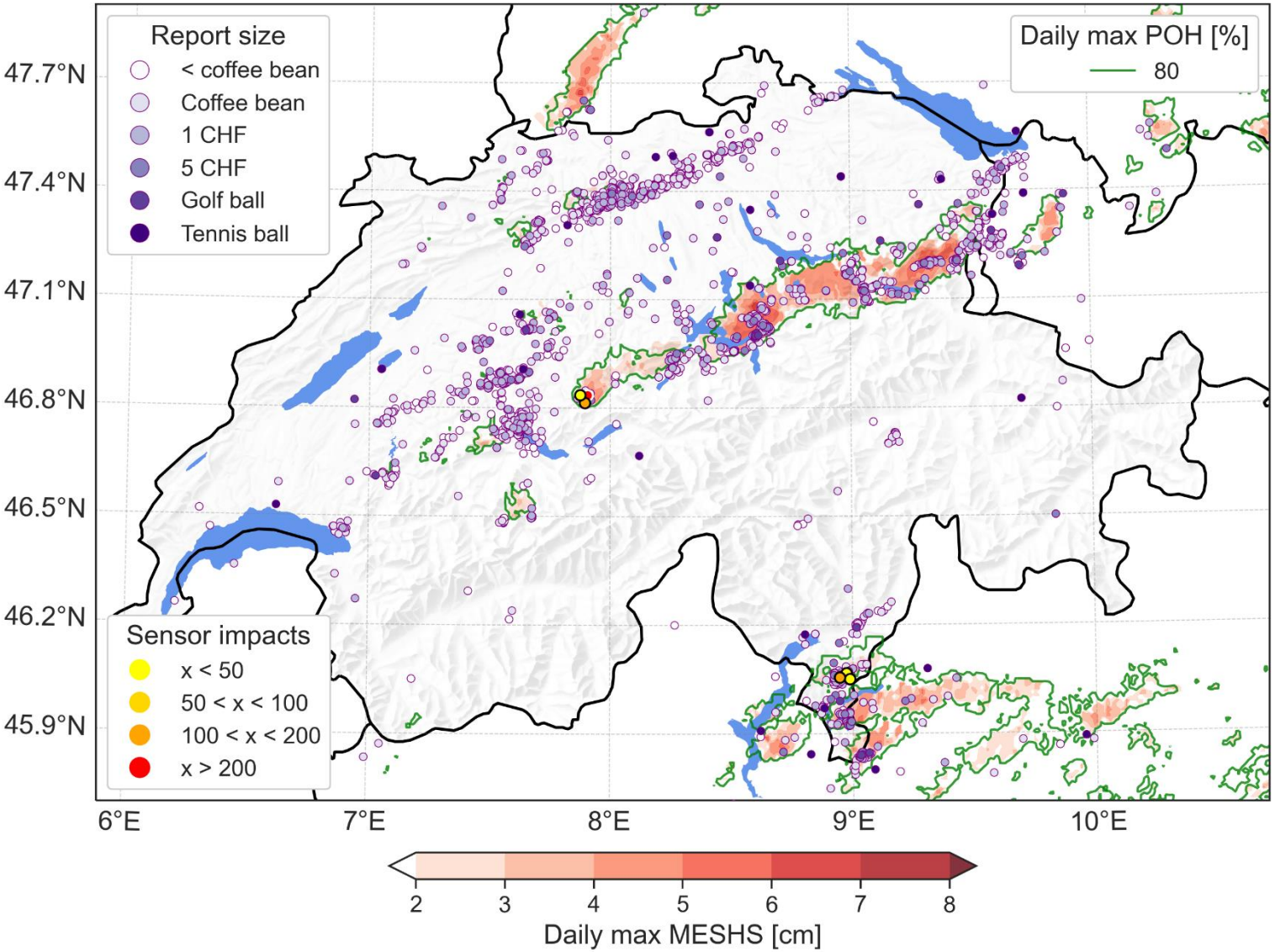


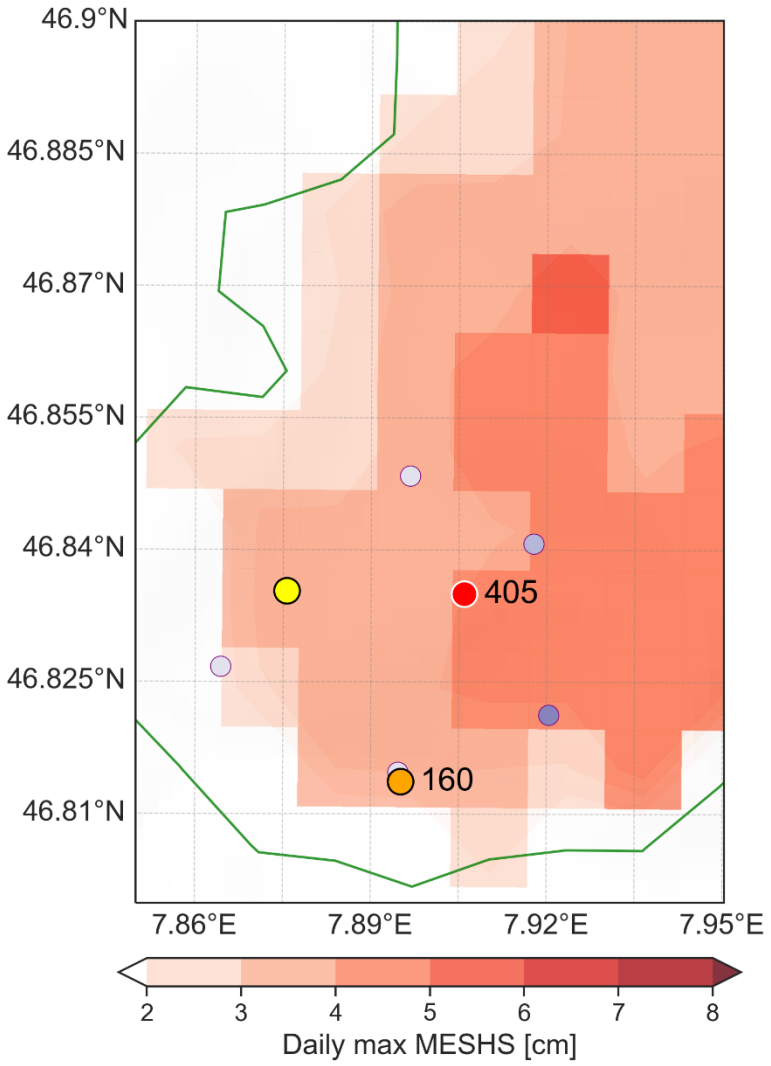


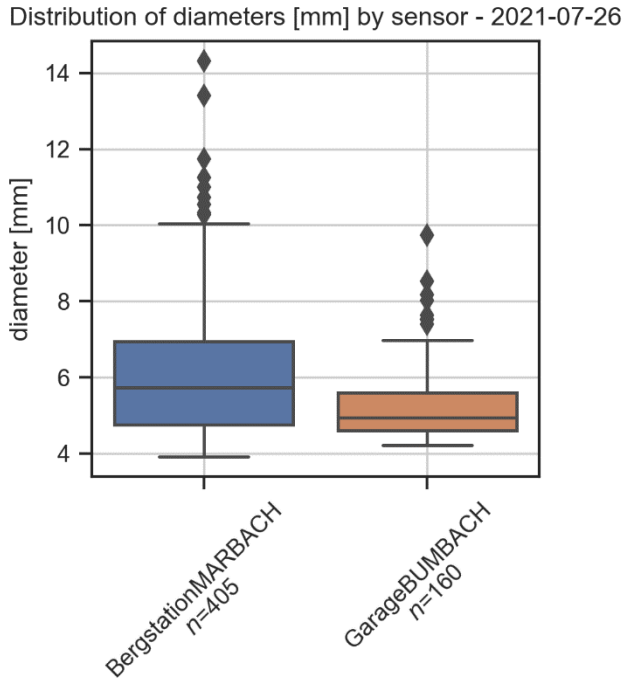


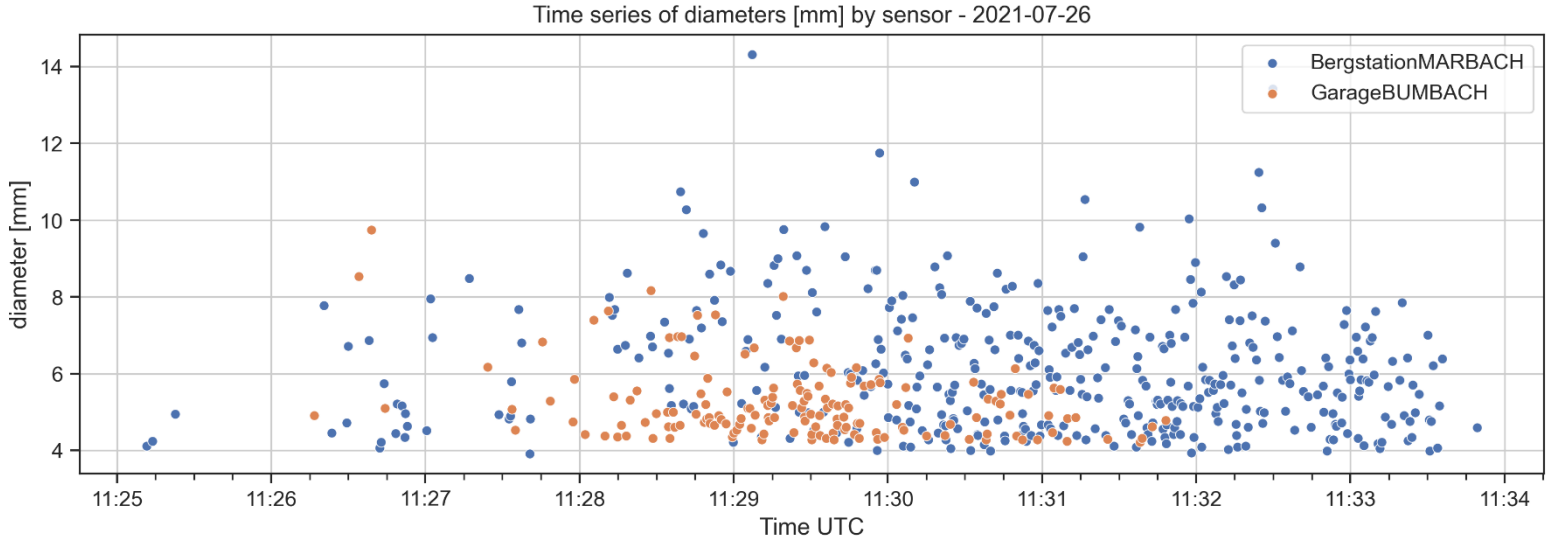
26.07.2021 – Napf and Ticino



26.07.2021 – Napf (sensors > 30 impacts)







- Some impacts before 1125UTC and after 1134UTC are not shown

26.07.2021 – Ticino (sensors > 30 impacts)