# Hail time series from radar proxies for decadal variability of hail in Switzerland


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## Motivation

**Hailstorms** in Switzerland regularly cause substantial damage and costs.

Recent studies showed significant differences in interannual hail variability north and south of the Alps (Barras et al. 2021, Nisi et al. 2018, 2020). However, an analysis of the long-term variability or changes in seasonality and its drivers is still missing.
To do that a new **daily hail time series** for Northern and Southern Switzerland from 1950 to today is produced.

## Data - POH

Empirical hail detection algorithm to estimate the

### Probability of Hail (POH)

of any size at the ground (Waldvogel et al. 1979, Foote et al. 2005).

Based on the vertical distance between the 45 dBz EchoTop height from the radar measurement and the freezing level height (COSMO-CH).

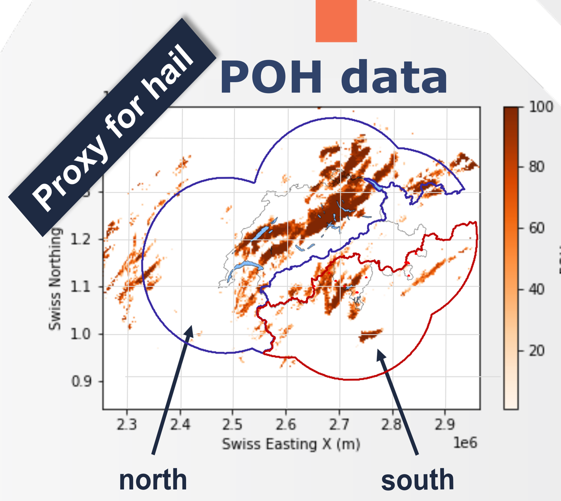
## Data - ERA5 Reanalysis

Model level (137 level, 0.5° x 0.5°), pressure level (17 lev., 0.5° x 0.5 °), surface data (0.25° x 0.25 °)

➞ **70 variables / indices** calculated that characterize conditional, latent and potential instabilities, moisture, advection and shear.

➞ For each variable the mean / max / min for a specific time of day was chosen and one absolute value was calculated for the region radar north and south.

# Hail in Switzerland



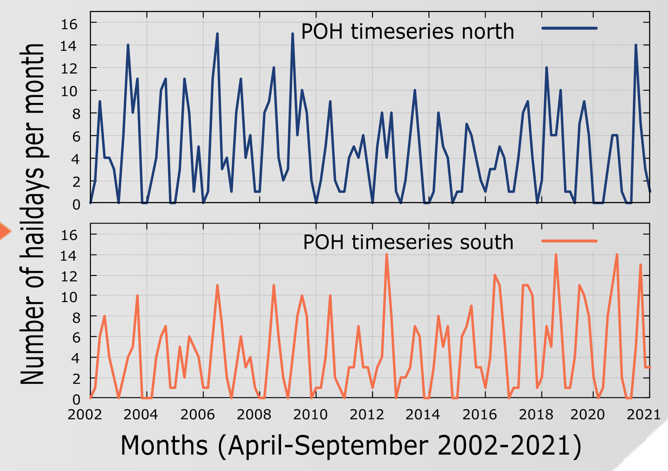

### Decision Hailday YES/NO:

**POH ≥ 80%**

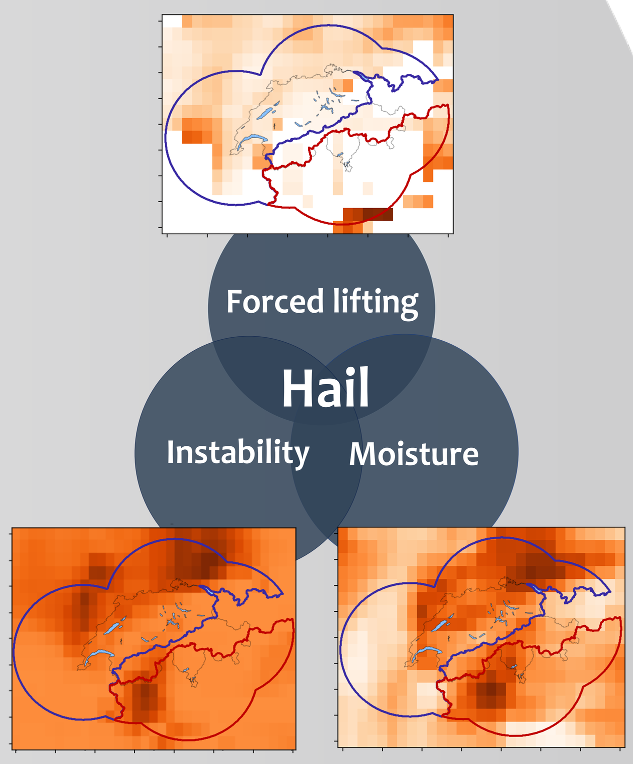
+

POH 80% area footprint
**≥ 499 / 580 km²**
(80th percentile of region south and north)

### POH time series




### Hail predictor variables from ERA5:




**ERA5 variables**
+
**POH time series**

### Logistic hail model

$$y = p_x = \frac{1}{1+e^{-g(x)}} \quad \text{with } 0 \le p_x \le 1$$

**North:**

$$g_{hailnorth} = \beta_0 + \beta_1 \times factor\,(month) + \beta_2 \times V_{500\,hPa} + \beta_3 \times \theta_{e850\,hPa} + \beta_4 \times \theta e_{500\,hPa} + \beta_5 \times T_{d2m} + \beta_6 \times \omega_{vint} + \beta_7 \times T_{500-700\,hPa}$$

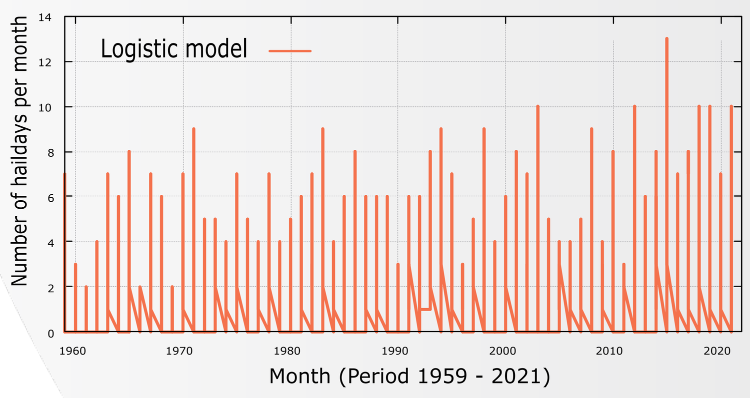
**South:**

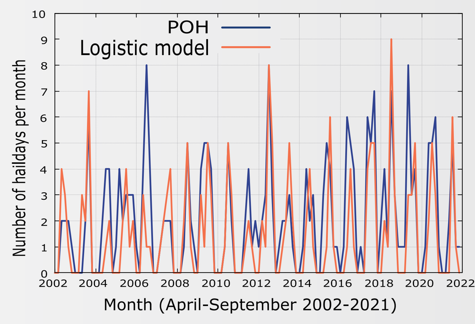
$$g_{hailsouth} = \beta_0 + \beta_1 \times factor\,(month) + \beta_2 \times Td_{2m} + \beta_3 \times SLI + \beta_4 \times WS_{0-6km} + \beta_5 \times T_{2m} + \beta_6 \times TT$$

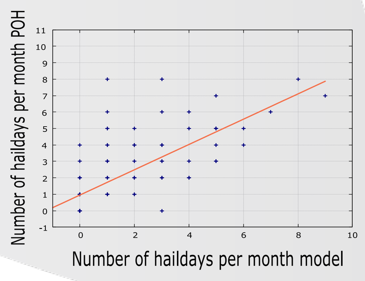
**Verification:**

| | North | South |
|---|---|---|
| AIC | 611.1 | 867.7 |
| BIC | 688.3 | 933.9 |
| CSI | 0.92 | 0.89 |
| POD | 0.95 | 0.93 |
| FAR | 0.03 | 0.04 |
| Acc. | 0.93 | 0.9 |

### Hail time series south




## Outlook

Use models to predict haildays back until 1950

Produce GAM-model and compare to logistic model

Study local and remote drivers of interannual variability and identify changes in seasonality

## Results

Model predictors match those found in the literature (Madonna et al. 2018, Mohr et al. 2015).

Good model performance by both models with 93 % / 90% accuracy for the test datasets.

Interannual variability and seasonality more or less reflected by both models, however, over- and especially underprediction are still problematic. Extreme values remain difficult to predict in both regions.

Model in region north generally shows better performance.

➞ **Logistic regression suitable for hailday prediction based on radar proxies**, however, other models should be tested

## Logistic regression

Multiple logistic regression model to predict haildays as a function of different meteorological factors $\{x_1, x_2, \dots, x_n\}$ as in-dependent variables.

Threshold value is set to $p_{hail} \ge 0.5$.

- **Stepwise bidirectional predictor selection** with **VIF** pre-treatment ( ≤ 4) to remove multicollinearity, **AIC / BIC** optimization, and expert judgement.
- **Seasonality** is addressed by a factor (month) as categorical predictor and **long-term trends** by the variable year (absolute value).
- Verification with independent test dataset. Metrics CSI, POD, FAR and accuracy were considered to find the best model.

| Variable | Explanation |
|---|---|
| $Td_{2m}$ | Dewpoint temperature at 2 m |
| $T_{2m}$ | Temperature at 2 m |
| $T_{500\,hPa - 700\,hPa}$ | Lapse rate between 500 hPa and 700 hPa |
| TT | $TT = T_{850\,hPa} + Td_{850\,hPa} - 2\,(T850\,hPa - T500\,hPa)$ |
| SLI | $SLI = T_{500\,hPa} - T`_{Surface \to 500\,hPa}$ |
| $\theta_{e\,500\,hPa}$ | Equivalent potential temperature at 500 hPa |
| $\theta_{e\,850\,hPa}$ | Equivalent potential temperature at 850 hPa |
| $WS_{0\,km - 6\,km}$ | Windshear between 10 m and 6 km (vector difference) |
| $v_{500\,hPa}$ | V - component of wind (northward) |
| $Q_{vint}$ | Vertically integrated specific humidity (over 1000 hPa - 10 hPa) |
| $\omega_{vint}$ | Vertically integrated vertical velocity (over 1000 hPa - 10 hPa) |


**References:**

E. Madonna et al., A Poisson regression approach to model monthly hail occurrence in NorthernSwitzerland using large-scale environmental variables, Atmospheric Research 203, 261 (2018),10.1016/j.atmosres.2017.11.024.
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