# Modelling snow interception in a spruce forest in varying climate

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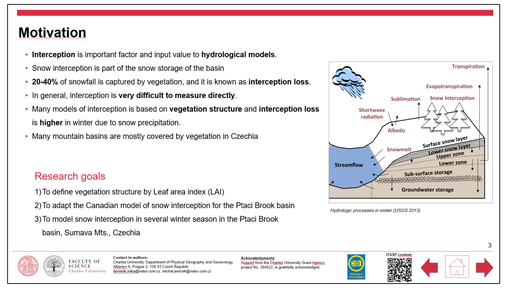
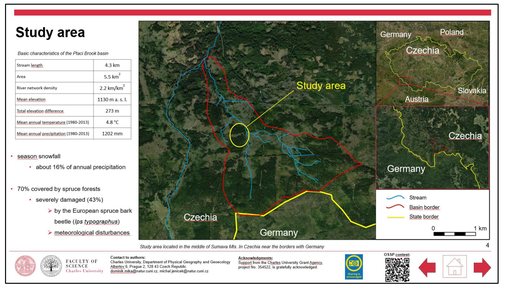
# Modelling snow interception in a spruce forest in varying climate

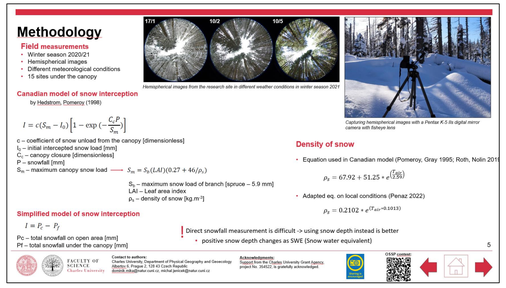
## Motivation



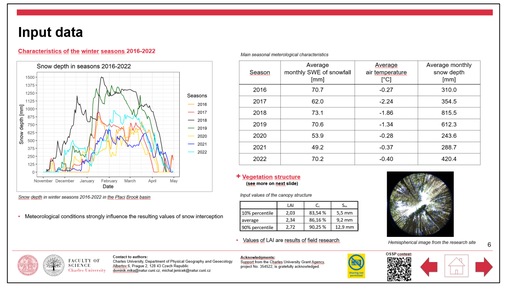

## Study area



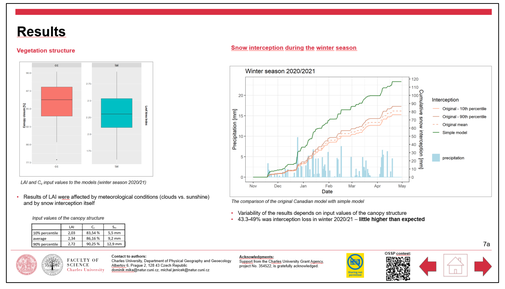

## Methodology



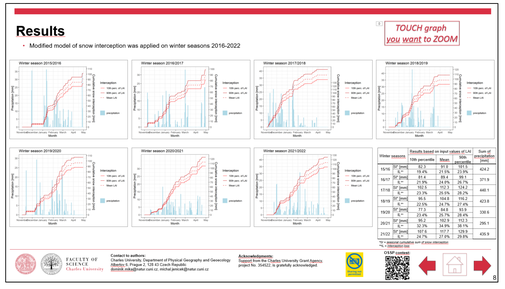

## Input data



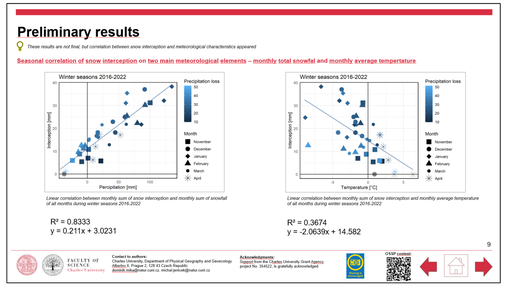

## Results - analyzing



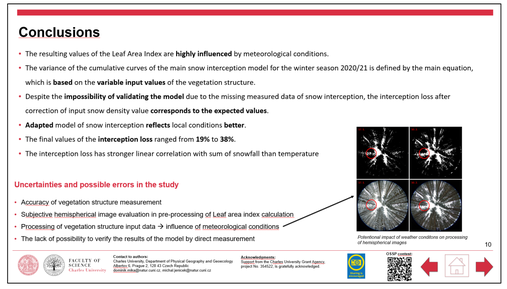

## Results - seasons




## Preliminary results




## Conclusions



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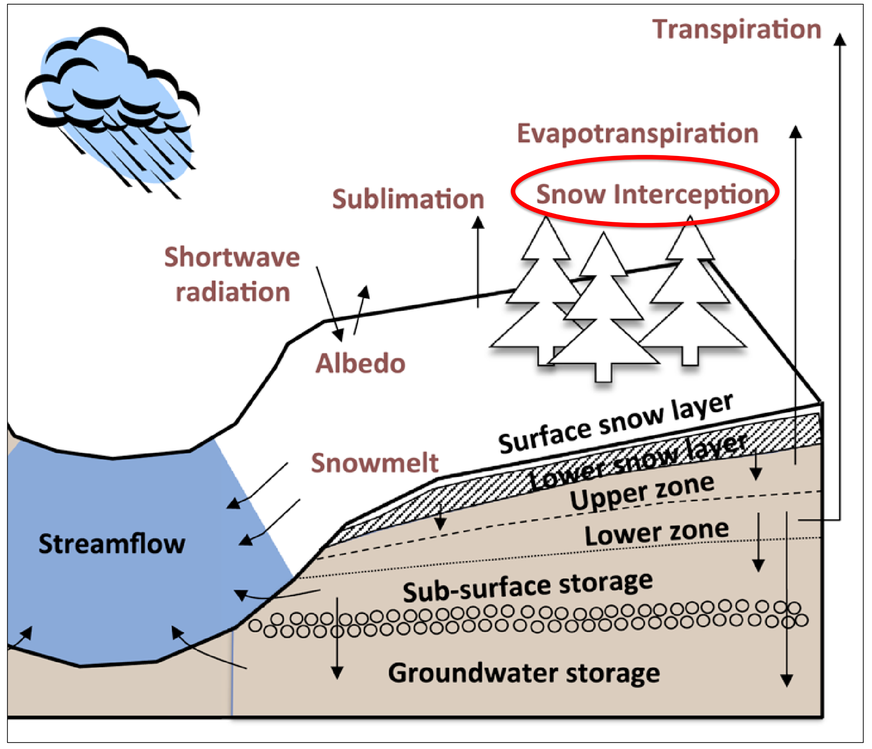
# Motivation

- **Interception** is important factor and input value to **hydrological models**.
- Snow interception is part of the snow storage of the basin
- **20-40%** of snowfall is captured by vegetation, and it is known as **interception loss**.
- In general, interception is **very difficult to measure directly**.
- Many models of interception is based on **vegetation structure** and **interception loss** is **higher** in winter due to snow precipitation.
- Many mountain basins are mostly covered by vegetation in Czechia




*Hydrologic processes in winter (USGS 2013)*

## Research goals

1) To define vegetation structure by Leaf area index (LAI)
2) To adapt the Canadian model of snow interception for the Ptaci Brook basin
3) To model snow interception in several winter season in the Ptaci Brook basin, Sumava Mts., Czechia



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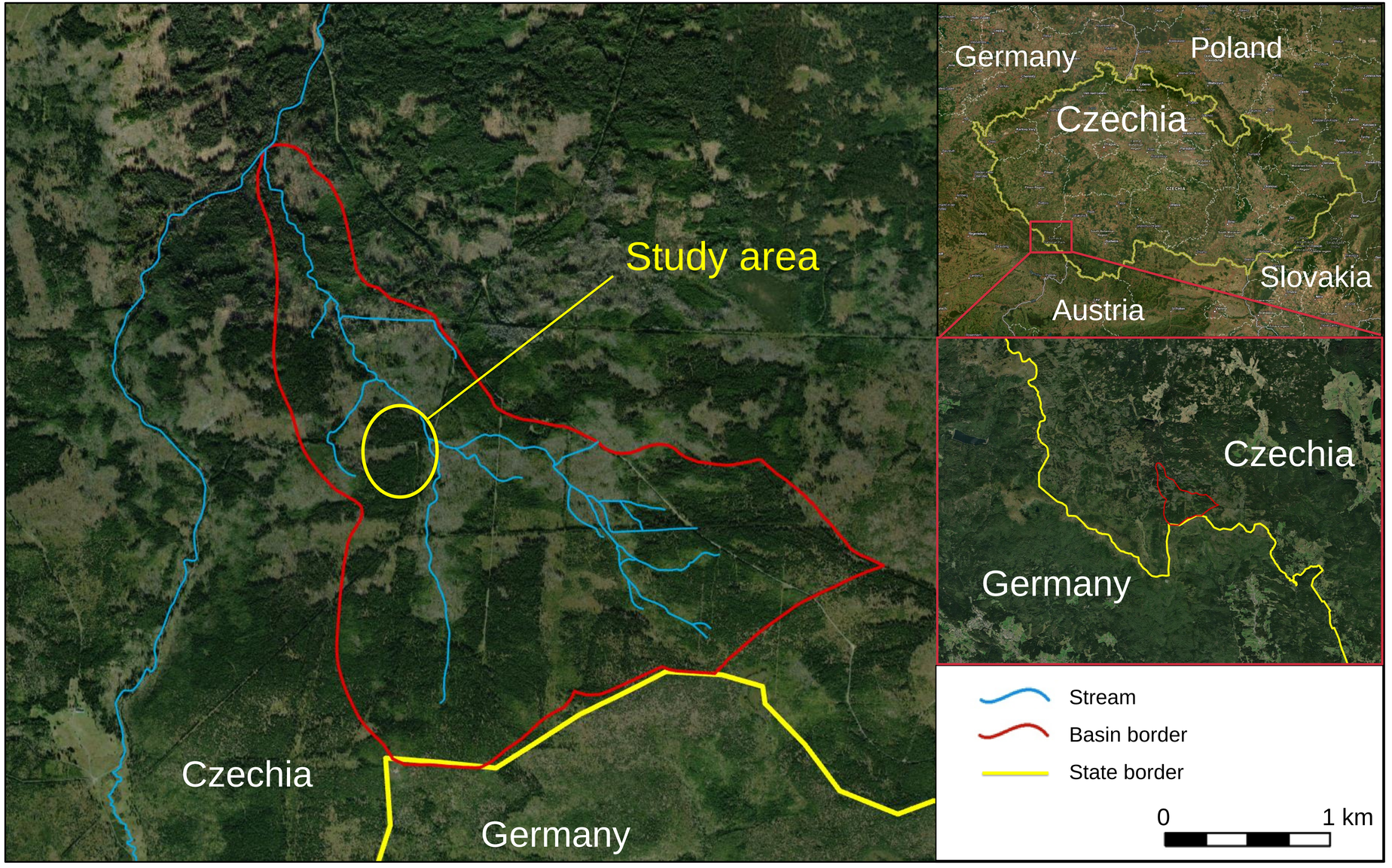
# Study area

*Basic characteristics of the Ptaci Brook basin*

| | |
|---|---|
| Stream length | 4.3 km |
| Area | 5.5 $km^2$ |
| River network density | 2.2 $km/km^2$ |
| Mean elevation | 1130 m a. s. l. |
| Total elevation difference | 273 m |
| Mean annual temperature (1980-2013) | 4.8 °C |
| Mean annual precipitation (1980-2013) | 1202 mm |

- Located in Šumava National Park
- season snowfall
  - about 16% of annual precipitation
- 70% covered by spruce forests
  - severely damaged (43%)
    - by the European spruce bark beetle (*Ips typographus*)
    - meteorological disturbances




*Study area located in the middle of Sumava Mts. In Czechia near the borders with Germany*



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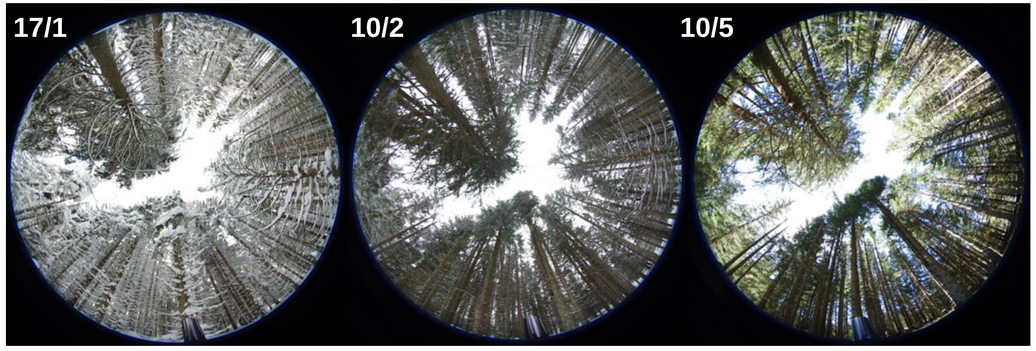
# Methodology

## Field measurements

- Winter season 2020/21
- Hemispherical images
- Different meteorological conditions
- 15 sites under the canopy




*Hemispherical images from the research site in different weather conditions in winter season 2021*

*Capturing hemispherical images with a Pentax K-5 IIs digital mirror camera with fisheye lens*

## Canadian model of snow interception

by Hedstrom, Pomeroy (1998)

$$I = c(S_m - I_0)\left[1 - \exp\left(-\frac{C_c P}{S_m}\right)\right]$$

c – coefficient of snow unload from the canopy [dimensionless]
$I_0$ – initial intercepted snow load [mm]
$C_c$ – canopy closure [dimensionless]
P – snowfall [mm]
$S_m$ – maximum canopy snow load $\longrightarrow$ $S_m = S_b(LAI)(0.27 + 46/\rho_s)$

*by Schmidt, Gluns (1991)*

$S_b$ – maximum snow load of branch [spruce – 5.9 mm]
LAI – Leaf area index
$\rho_s$ – density of snow [kg.m$^{-3}$]

## Simple equation of snow interception

$$I = P_c - P_f$$

Pc – total snowfall on open area [mm]
Pf – total snowfall under the canopy [mm]

## Density of snow

- Equation used in Canadian model (Schmidt, Gluns 1991)

$$\rho_s = 67.92 + 51.25 * e^{\left(\frac{T_{air}}{2.59}\right)}$$

- Adapted eq. on local conditions (Penaz 2022)

$$\rho_s = 0.2102 * e^{(T_{air} * 0.1013)}$$

**!** There were NO possibility to measure snow interception directly

- We do not have a snow interception measurement device.
- All possible ways of direct measurements are not „nature friendly“ – study area is in Šumava National Park



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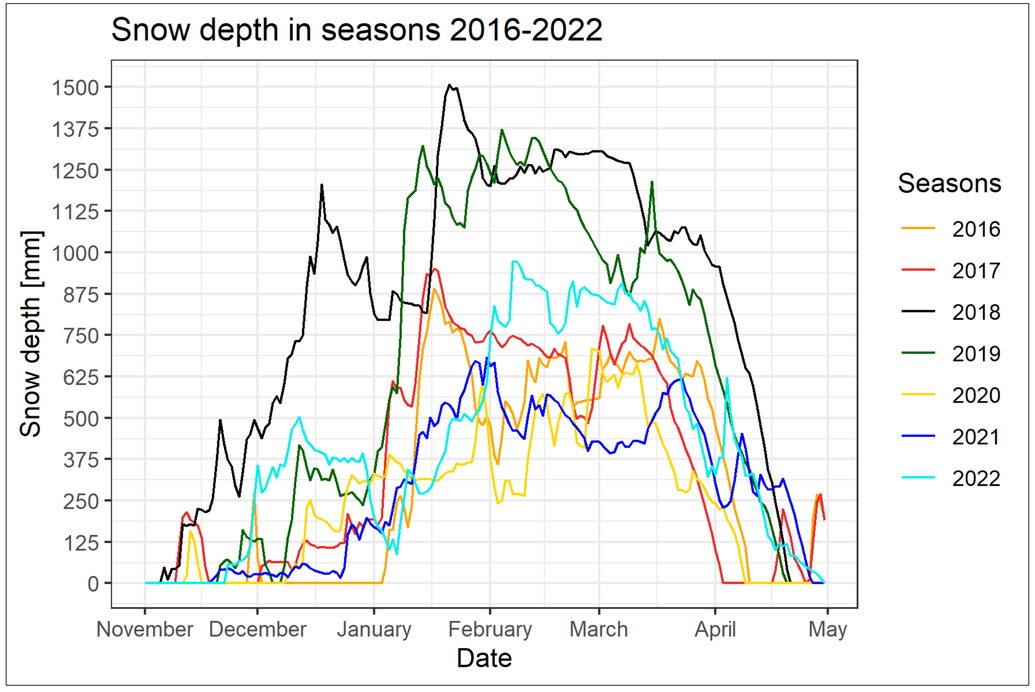
# Input data

## Characteristics of the winter seasons 2016-2022




*Snow depth in winter seasons 2016-2022 in the Ptaci Brook basin*

- Meteorological conditions strongly influence the resulting values of snow interception

*Main seasonal meterological characteristics*

| Season | Average monthly SWE of snowfall [mm] | Average air temperature [°C] | Average monthly snow depth [mm] |
|---|---|---|---|
| 2016 | 70.7 | -0.27 | 310.0 |
| 2017 | 62.0 | -2.24 | 354.5 |
| 2018 | 73.1 | -1.86 | 815.5 |
| 2019 | 70.6 | -1.34 | 612.3 |
| 2020 | 53.9 | -0.28 | 243.6 |
| 2021 | 49.2 | -0.37 | 288.7 |
| 2022 | 70.2 | -0.40 | 420.4 |

## + Vegetation structure

**(see more on next slide)**

*Input values of the canopy structure*

| | LAI | $C_c$ | $S_m$ |
|---|---|---|---|
| 10% percentile | 2,03 | 83,54 % | 5,5 mm |
| average | 2,34 | 86,16 % | 9,2 mm |
| 90% percentile | 2,72 | 90,25 % | 12,9 mm |

- Values of LAI are results of field research

*Hemispherical image from the research site*



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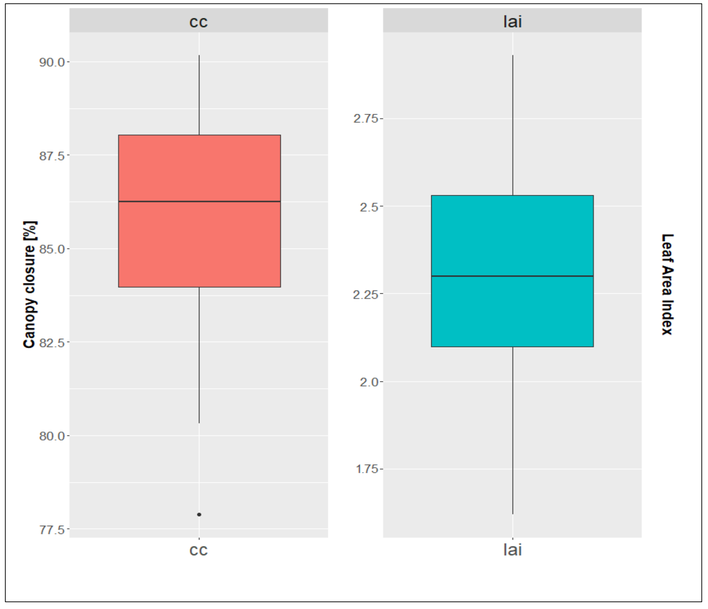
# Results

## Vegetation structure




*LAI and $C_c$ input values to the models (winter season 2020/21)*

- Results of LAI were affected by meteorological conditions (clouds vs. sunshine) and by snow interception itself

*Input values of the canopy structure*

| | LAI | $C_c$ | $S_m$ |
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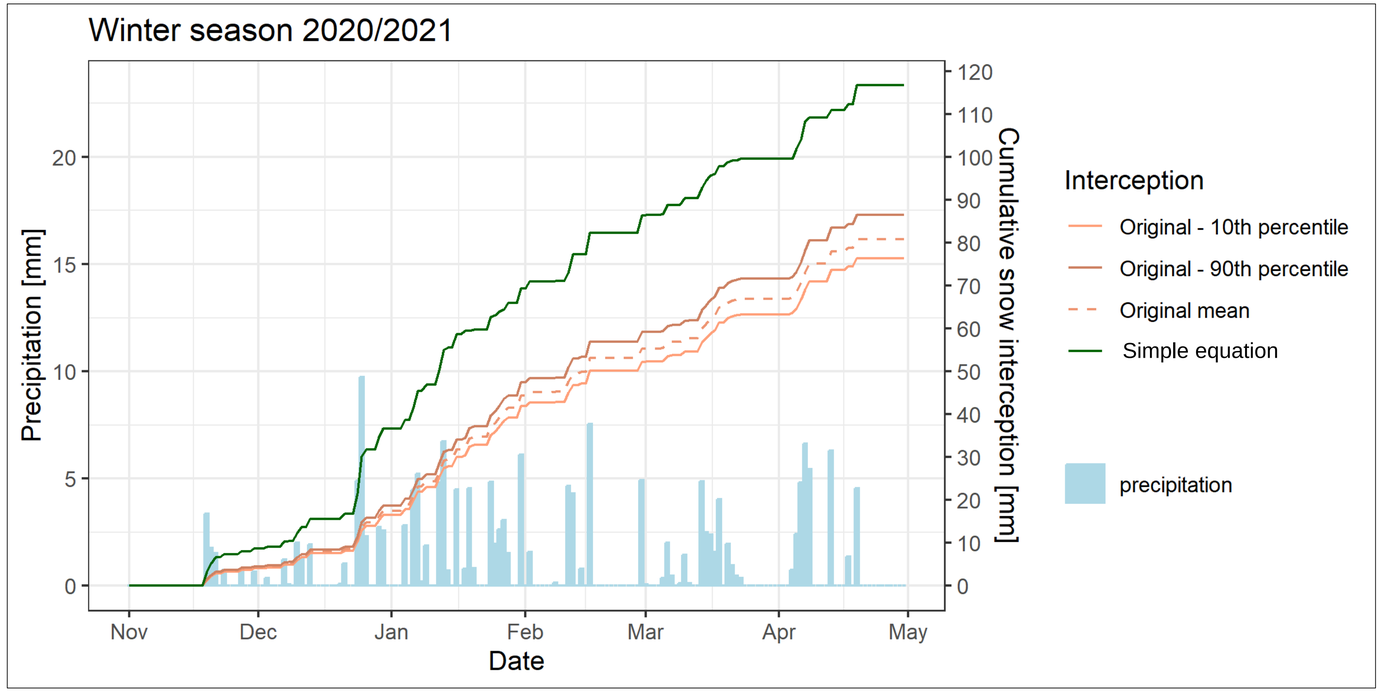
## Snow interception during the winter season




*The comparison of the original Canadian model with simple model*

- Variability of the results depends on input values of the canopy structure
- 43.3-49% was interception loss in winter 2020/21 – **little higher than expected**



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# Results

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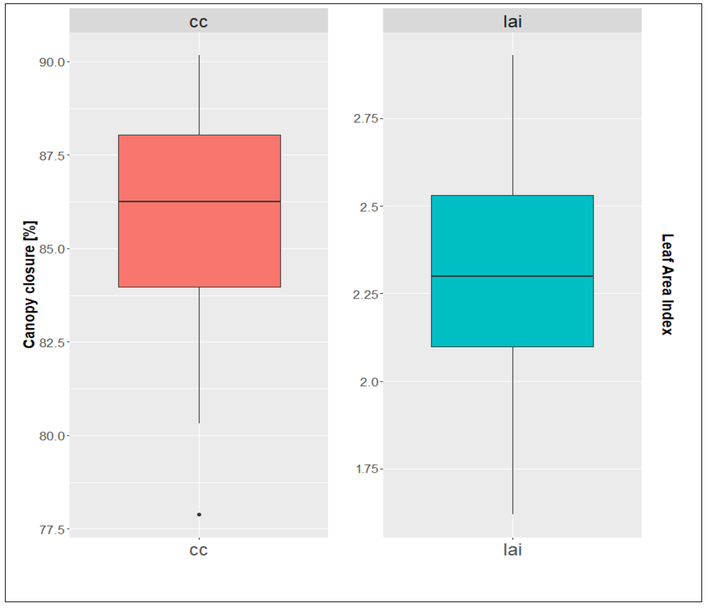


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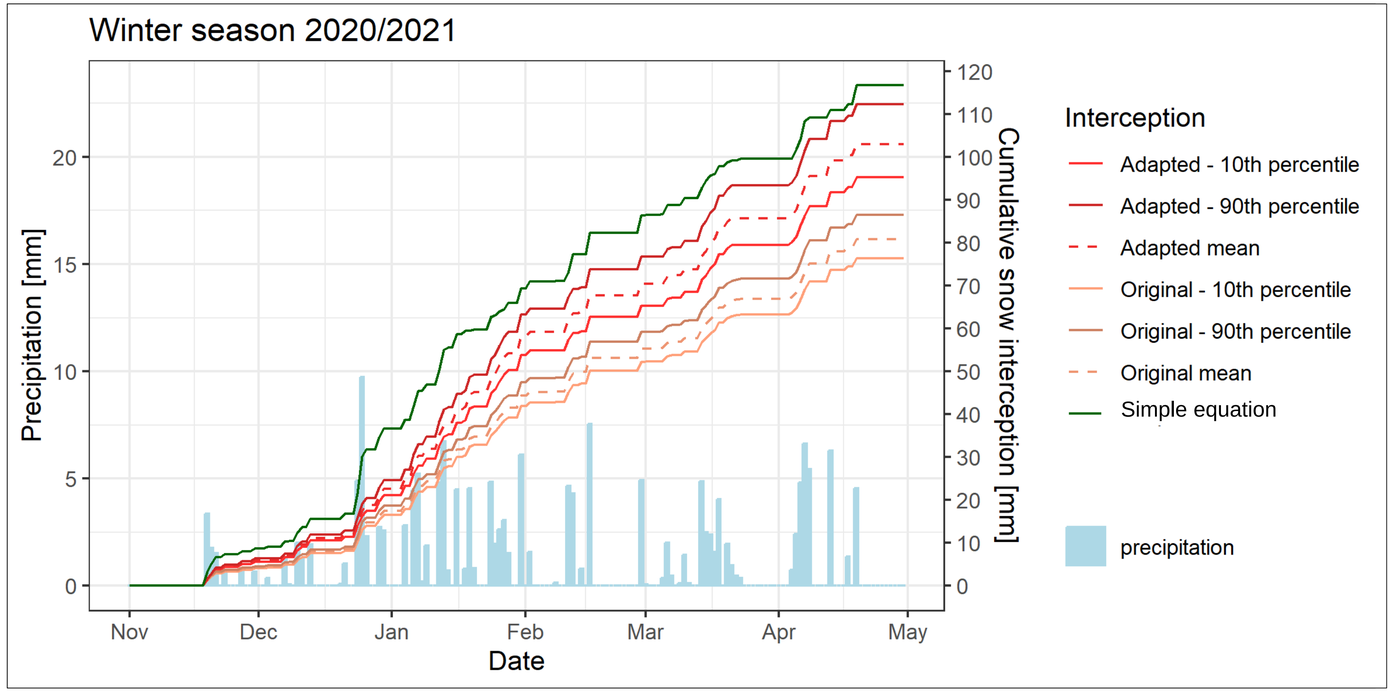


*The comparison of the original Canadian model with simple model and adapted Canadian model*

- Variability of the results depends on input values of the canopy structure
- 43.3-49% was interception loss in winter 2020/21 – **little higher than expected**

- Little adaptation of orginal model – new input equation of density of snow – adapted eq. from Penaz (2022)
- 24.7-29.8% was interception loss in winter 2020/21 after using local eq. of density of snow
- These results correspond **more closely to real values**

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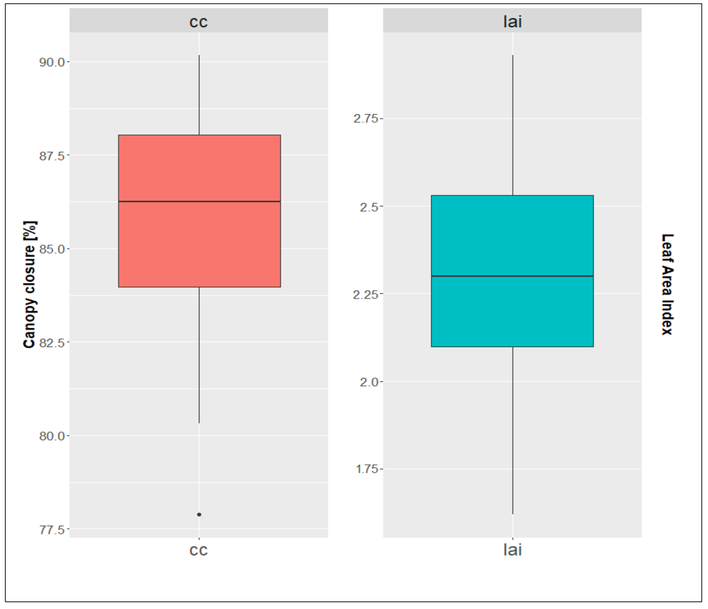
# Results

## Vegetation structure

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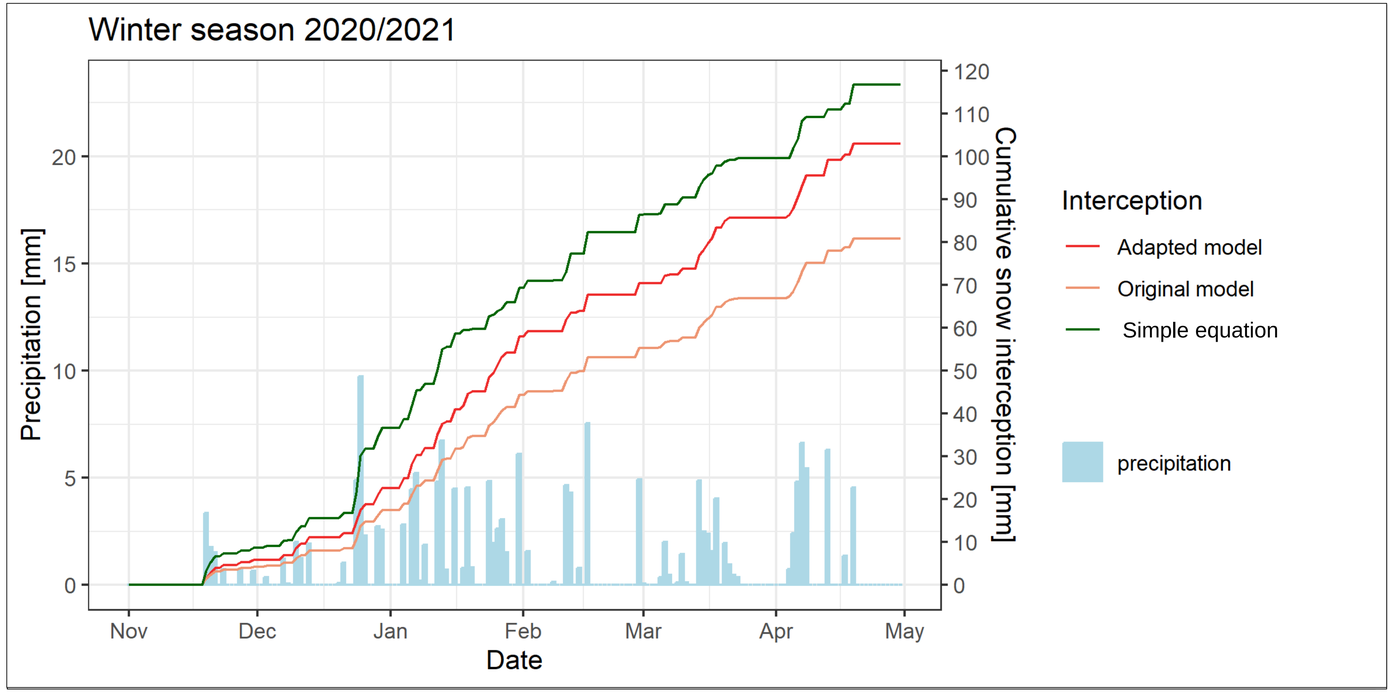
## Snow interception during the winter season




*The comparison of the original Canadian model with simple model and adapted Canadian model – mean values*

- Variability of the results depends on input values of the canopy structure
- 43.3-49% was interception loss in winter 2020/21 – **little higher than expected**

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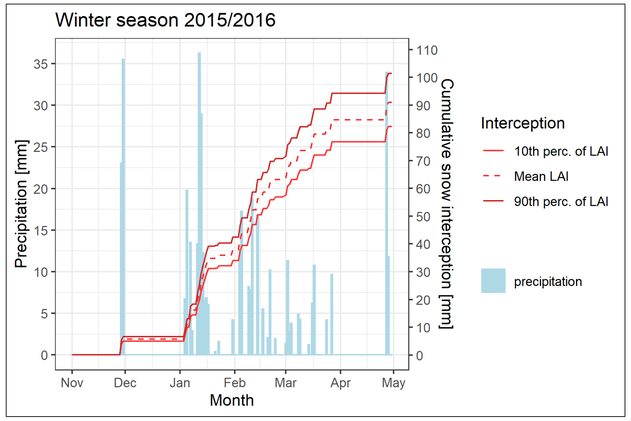
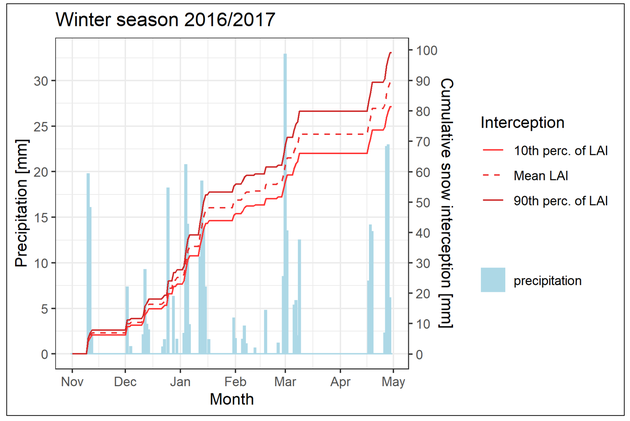
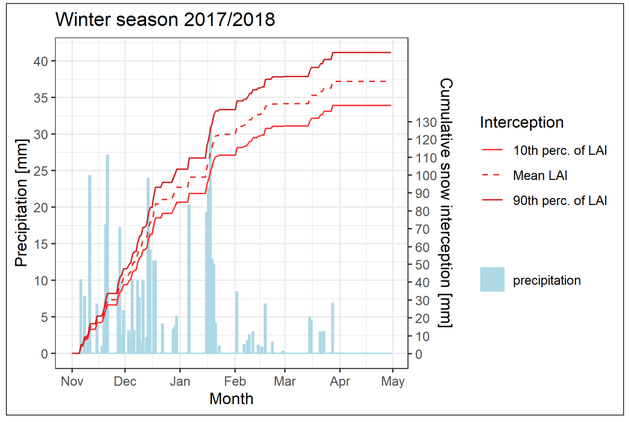
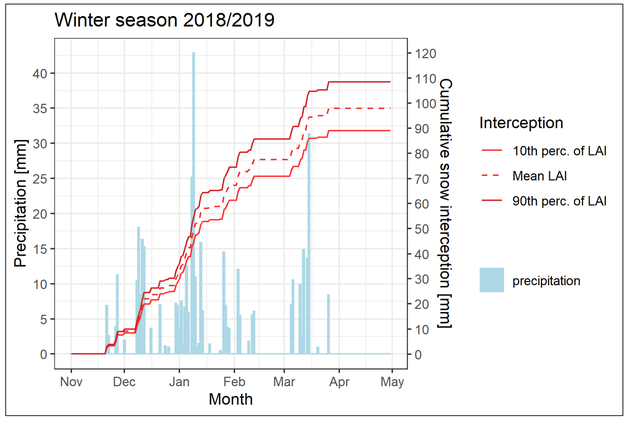
# Results

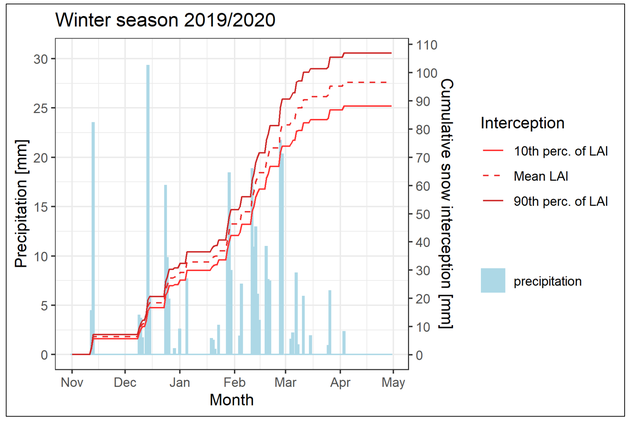
- Modified model of snow interception was applied on winter seasons 2016-2022

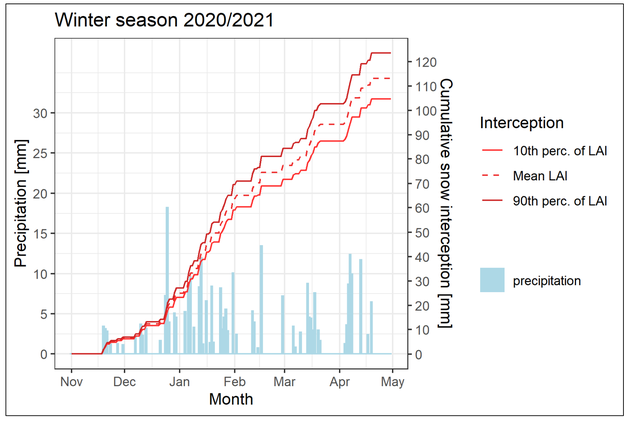


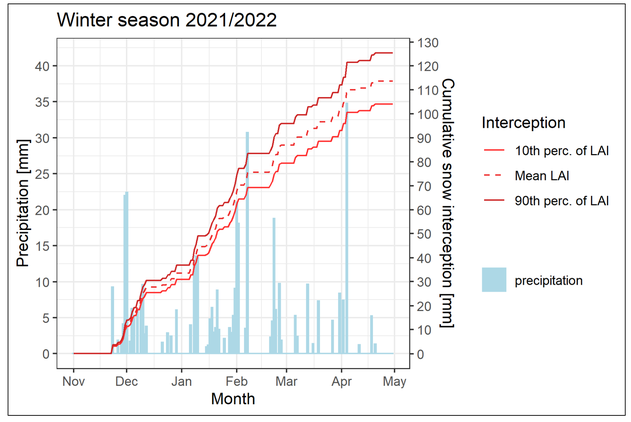




| Winter seasons | | Results based on input values of LAI | | | Seasonal snowfall [mm] |
|---|---|---|---|---|---|
| | | 10th percentile | Mean | 90th percentile | |
| 15/16 | SI* [mm] | 82.3 | 91.0 | 101.5 | 424.2 |
| | IL** | 19.4% | 21.5% | 23.9% | |
| 16/17 | SI* [mm] | 81.4 | 89.4 | 99.1 | 371.9 |
| | IL** | 21.9% | 24.0% | 26.7% | |
| 17/18 | SI* [mm] | 102.5 | 112.3 | 124.2 | 440.1 |
| | IL** | 23.3% | 25.5% | 28.2% | |
| 18/19 | SI* [mm] | 95.5 | 104.8 | 116.2 | 423.8 |
| | IL** | 22.5% | 24.7% | 27.4% | |
| 19/20 | SI* [mm] | 77.3 | 84.8 | 93.9 | 330.6 |
| | IL** | 23.4% | 25.7% | 28.4% | |
| 20/21 | SI* [mm] | 95.2 | 102.9 | 112.3 | 295.1 |
| | IL** | 32.3% | 34.9% | 38.1% | |
| 21/22 | SI* [mm] | 107.6 | 117.7 | 129.9 | 435.9 |
| | IL** | 24.7% | 27.0% | 29.8% | |

**SI = seasonal cumulative sum of snow interception*
***IL = Interception loss*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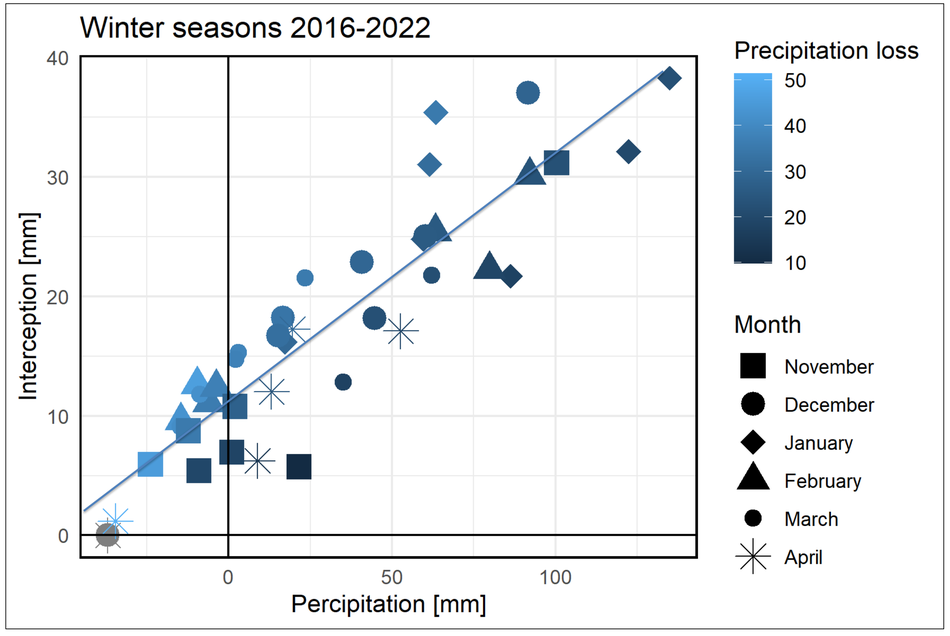
# Preliminary results

*These results are not final, but correlation between snow interception and meteorological characteristics appeared*

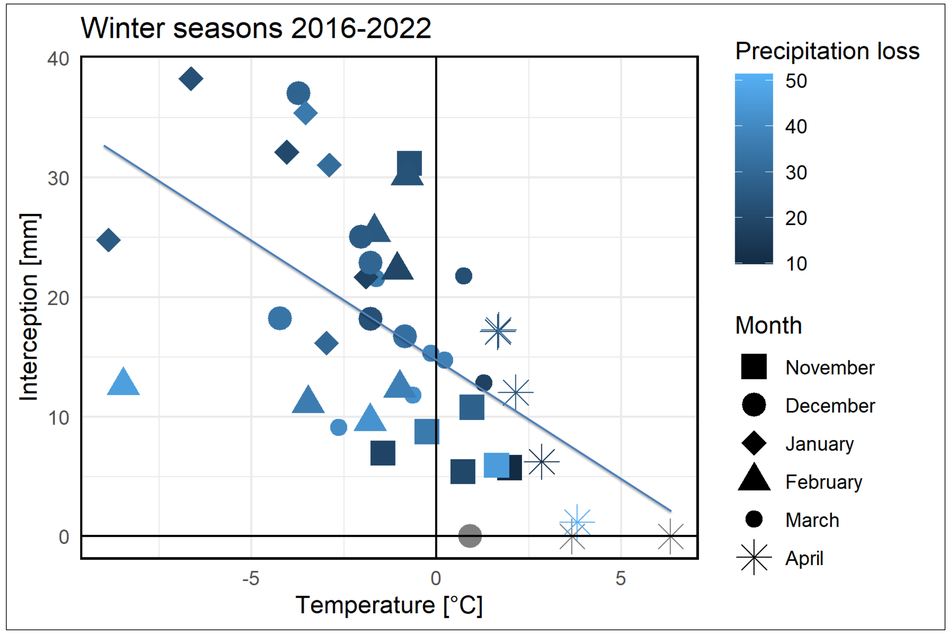
## Seasonal correlation of snow interception on two main meteorological elements – monthly total snowfal and monthly average tempertature




*Linear correlation between monthly sum of snow interception and monthly sum of snowfall of all months during winter seasons 2016-2022*

$R^2 = 0.8333$

$y = 0.211x + 3.0231$




*Linear correlation between monthly sum of snow interception and monthly average temperature of all months during winter seasons 2016-2022*

$R^2 = 0.3674$

$y = -2.0639x + 14.582$



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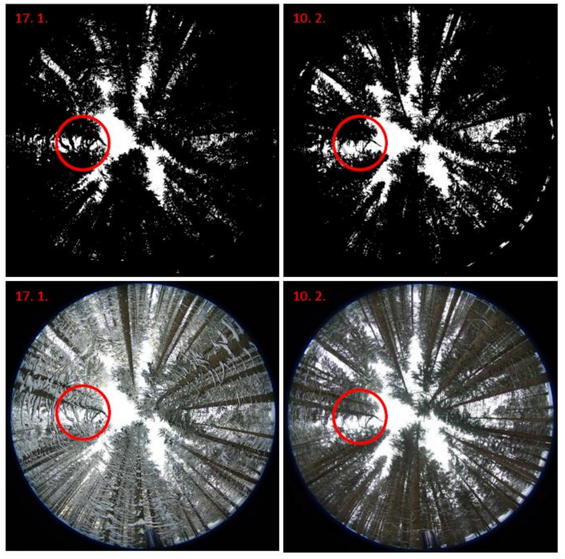
# Conclusions

- The resulting values of the Leaf Area Index are **highly influenced** by meteorological conditions.
- The variance of the cumulative curves of the main snow interception model for the winter season 2020/21 is defined by the main equation, which is **based** on the **variable input values** of the vegetation structure.
- Despite the **impossibility of validating the model** due to the missing measured data of snow interception, the interception loss after correction of input snow density value **corresponds to the expected values**.
- **Adapted** model of snow interception **reflects** local conditions **better**.
- The final values of the **interception loss** ranged from **19%** to **38%**.
- The interception loss has stronger linear correlation with sum of snowfall than temperature

## Uncertainties and possible errors in the study

- Accuracy of vegetation structure measurement
- Subjective hemispherical image evaluation in pre-processing of Leaf area index calculation
- Processing of vegetation structure input data → influence of meteorological conditions
- The lack of possibility to verify the results of the model by direct measurements




*Potentional impact of weather conditons on processing of hemispherical images*



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