Determination of solid precipitation occurrence using ALADIN model outputs

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Motivation & Methods

- Declining number of human present weather observers → need for a different method of present weather evaluation
- Use of **ALADIN NWP model** outputs (e.g., Sokol et al., 2022) – **good spatial coverage** (2.3 km resolution), useful for weather damage reports etc.

Calculation of ALADIN_SNOW weighted probability

- Assumption: shorter lead times → better accuracy; model run every 6 hours (00, 06, 12, 18 UTC)
- Four model runs taken into account for every 1h forecast → lead time up to 24 h
- **Weights** assigned to every forecast, ALADIN_SNOW = **sum** of all weights in a 6h interval where forecasted amount of **solid precipitation > 0** divided by 300 (highest possible total)

WEIGHTS

Forecast time (h)	Model run (h) -18	-12	-6	0
+1	6	12	18	24
+2	5	11	17	23
+3	4	10	16	22
+4	3	9	15	21
+5	2	8	14	20
+6	1	7	13	19

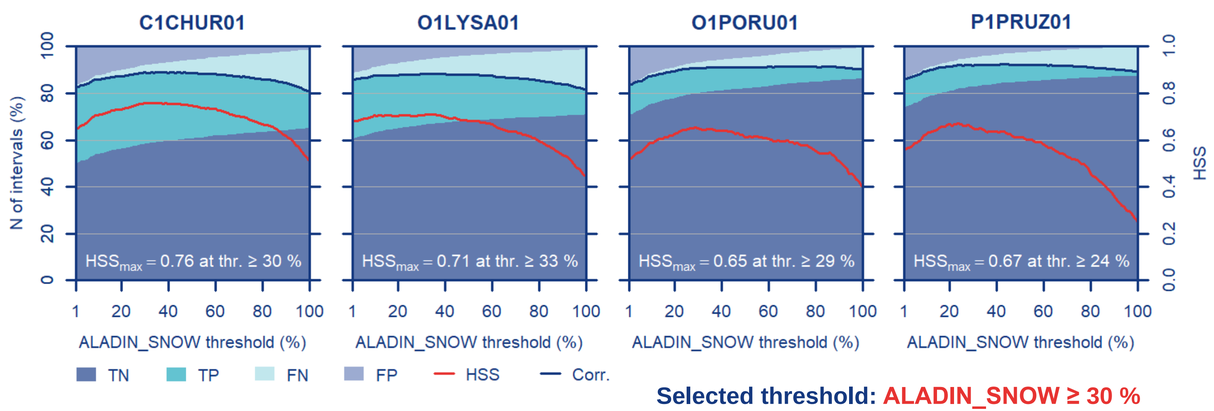
EXAMPLE

Forecast time (h)	Model run (h) -18	-12	-6	0
+1	TRUE	TRUE	TRUE	FALSE
+2	TRUE	TRUE	TRUE	TRUE
+3	FALSE	TRUE	FALSE	FALSE
+4	FALSE	TRUE	FALSE	FALSE
+5	FALSE	FALSE	FALSE	TRUE
+6	FALSE	FALSE	TRUE	FALSE

ALADIN_SNOW (ex.) = (5 + 6 + 9 + 10 + 11 + 12 + 13 + 17 + 18 + 20 + 23) / 300 = **41.3 %**

Optimal threshold selection

Selected metrics calculated for various ALADIN_SNOW thresholds from ALADIN_SNOW ≥ 1 % to ALADIN_SNOW = 100 %, with a **1 % step**



Selected threshold: ALADIN_SNOW ≥ 30 %

ALADIN_SNOW outside the snow period

- In total, 71, 17, 1, and 7 intervals with at least one solid precipitation observation and 98, 0, 3, and 1 intervals with a solid precipitation prediction at C1CHUR01, O1LYSA01, O1PORU01, and P1PRUZ01, respectively.
- At C1CHUR01, 34 out of 71 intervals with a solid prec. observation were recorded in May, and 25 in October (transition period)
- Much **worse skill** than in snow period, model has no or almost **no skill** in months with **less than ~ 2 % of days with a solid precipitation observation** (rare cases)

Solid precipitation in summer (JUN, JUL, AUG)

- Only **7 intervals** with a solid precipitation observation in summer (2, 0, 3, 2 at C1CHUR01, O1LYSA01, O1PORU01, and P1PRUZ01, respectively)
- In 6 cases, the solid precipitation was **graupel**, in one case ice pellets, all cases linked to convection (thunderstorm at or near the station)
- **No positive predictions**: model can't detect rare summer solid precipitation but **does not confuse solid precipitation and hail**

Further steps

- Assess the performance of ALADIN_SNOW using **all the CHMI stations** that provide a continuous record of present weather observations and air temperature measurements
  - **Quality control** of the present weather observations may be needed
- Explore the possibility of using a **dynamical threshold** of ALADIN_SNOW, e.g., its dependence on station altitude
- Evaluate the **spatial characteristics** of ALADIN_SNOW performance using selected metrics, including its dependence on solid precipitation intensity, duration, and type, and on air temperature
- After the model performance assessment, calculate ALADIN_SNOW for **all available grid points** so it is ready for practical use within the CHMI network, to supplement the present weather observation and other meteorological characteristics measured at the individual stations

Present weather observations

ALADIN_SNOW validated against the solid precipitation present weather observations of trained professionals at **four CHMI stations** in **August 2019 – July 2025:**

- Churáňov (**C1CHUR01**): N 49.07, E 13.62, 1 118 m a.s.l.
- Lysá Hora (**O1LYSA01**): N 49.55, E 18.45, 1 322 m a.s.l.
- Ostrava Poruba (**O1PORU01**): N 49.83, E 18.16, 240 m a.s.l.
- Praha Ruzyně (**P1PRUZ01**): N 50.10, E 14.26, 364 m a.s.l.

Solid precipitation observations included snow (SN), sleet (SL), graupel (GR), ice pellets (IP), snow grains (SG), frozen rain (ZR)

Validation metrics

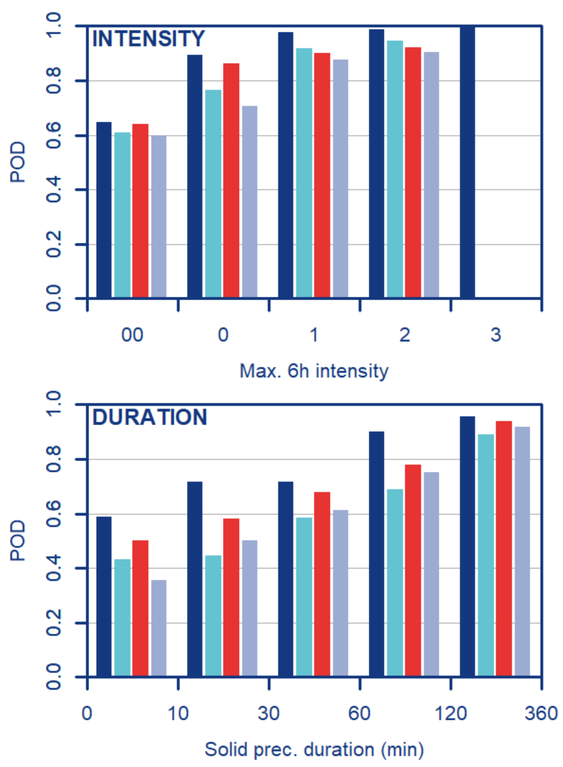
At a given ALADIN_SNOW threshold, every 6h interval was marked either as **TP** (True Positive, solid precipitation predicted and observed), **TN** (True Negative, solid precipitation neither predicted nor observed), **FP** (False Positive, solid precipitation predicted but not observed), and **FN** (False Negative, solid precipitation not predicted but observed), and the values of selected metrics were calculated:

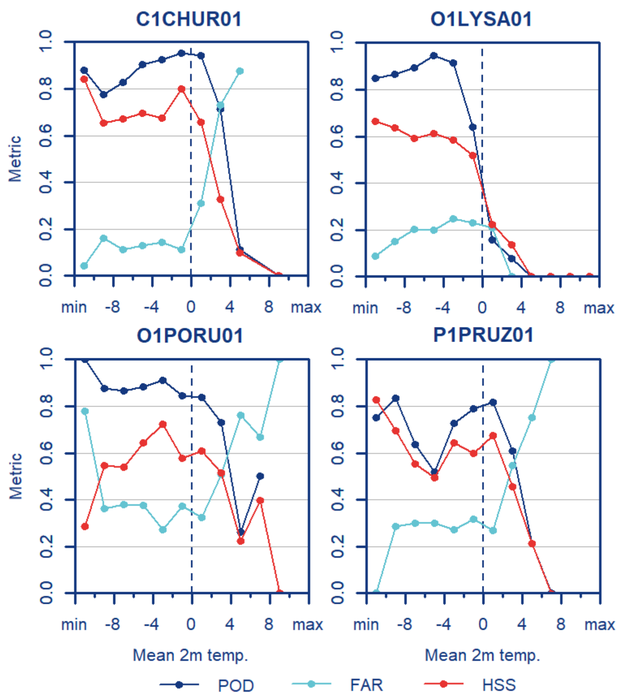
- **Percentage of Correct Predictions Corr. (%)** = 100 (TP + TN) / N
- **Probability of Detection POD** = TP / (TP + FN)
- **False Alarm Ratio FAR** = FP / (TP + FP)
- **Heidke Skill Score HSS** = 2 (TP×TN - FN×FP) / [(TP + FN)(FN + TN) + (TN + FP)(TP + FP)]

Most validation carried out for **snow period**, which was defined as **months with more than 10 % days with a solid precipitation record**.

ALADIN_SNOW performance in snow period

- Positive prediction: ALADIN_SNOW ≥ 30 % in 6h intervals
- **Good performance** with mean percentage of correct predictions, POD, FAR, and HSS = 90.0, 0.81, 0.28, and 0.69, respectively.
- Generally **better performance** at **higher altitudes** (C1CHUR01, O1LYSA01)
- Increase in model skill with the increase in solid precipitation **intensity** and **duration**
- Best skill when precipitation type = **SN**, but reasonable even for SL and GR; worst for IP where POD = 0.0 at all stations
- **Decline** in model skill with an **increase in temperature** (sharp drop at above ~ 2 °C)
- At higher air temperatures, up to 88 % of **FP** values coincide with **liquid precipitation**, only up to 21 % when temp. < 0 °C
- Use of **daily resolution** only brings **small improvement** of model skill → not worth the loss of temporal resolution, will not be used in practice





Dependence of selected metrics on mean 2m air temperature at four CHMI stations in 2019–2025, the dashed line indicates mean temp. = 0 °C.

Dependence of POD on solid precipitation maximum intensity, total duration, and type within the 6h intervals, and the total number of FP cases at different air temperatures supplemented by the number of FP intervals in which liquid precipitation was recorded (hatched) at four CHMI stations in 2019–2025.

SNOW PERIOD

	Corr. (%)	POD	FAR	HSS
C1CHUR01	88.9	0.91	0.21	0.76
O1LYSA01	88.3	0.78	0.21	0.71
O1PORU01	90.9	0.82	0.38	0.65
P1PRUZ01	92.0	0.73	0.33	0.65

OUTSIDE SNOW PERIOD

	Corr. (%)	POD	FAR	HSS
C1CHUR01	98.2	0.62	0.55	0.52
O1LYSA01	99.4	0.00	N/A	0.00
O1PORU01	99.9	0.00	1.00	0.00
P1PRUZ01	99.8	0.00	1.00	0.00

DAILY RES. (SN. P.)

	Corr. (%)	POD	FAR	HSS
C1CHUR01	89.3	0.93	0.14	0.78
O1LYSA01	87.9	0.81	0.09	0.71
O1PORU01	88.7	0.87	0.28	0.71
P1PRUZ01	90.1	0.86	0.25	0.73

References

Sokol, Z., Brožková, R., Popová, J., Bobotová, G., abd Švábik, F.: Evaluation of ALADIN NWP model forecasts by IR10.8 μm and WV06.2 μm brightness temperatures measured by the geostationary satellite Meteosat Second Generation. Atmos. Res., 265, 1–20, 2022, DOI: 10.1016/j.atmosres.2021.1.

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