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Supplement of

Impact of cloud seeding on simulated hailstorms and its dependence on CAPE, wind shear, and tracking thresholds

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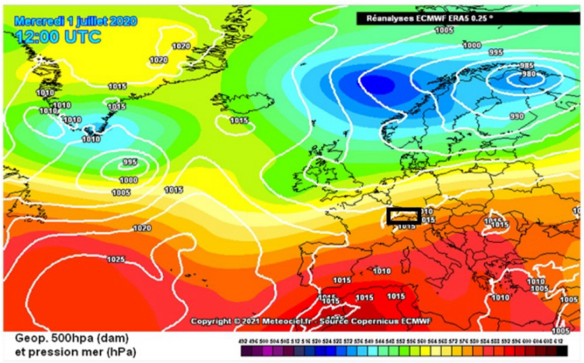
01.07.2020



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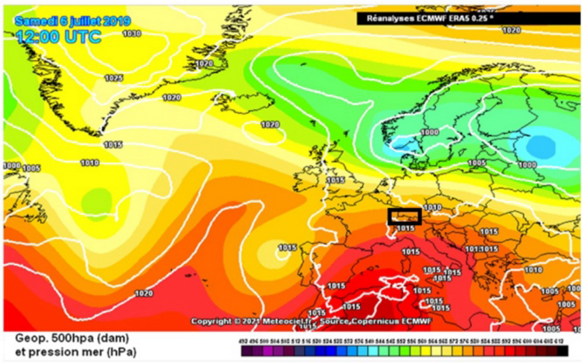

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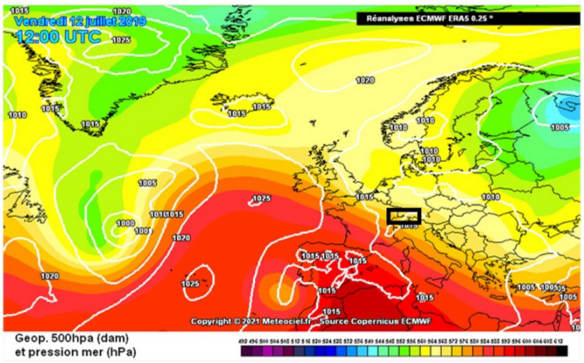

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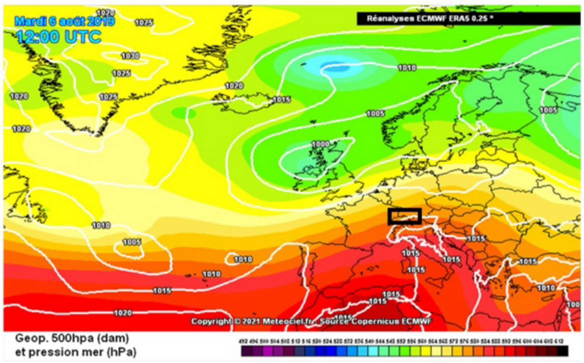

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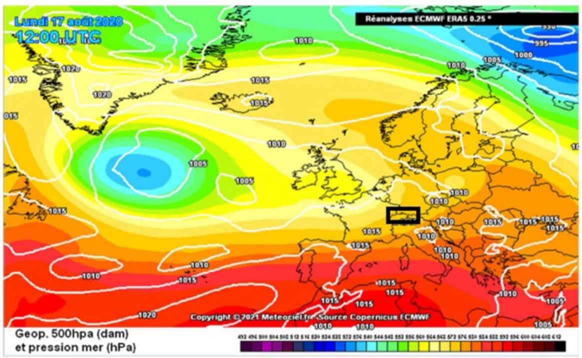

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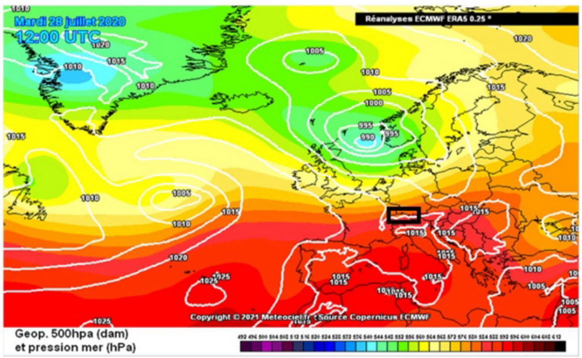

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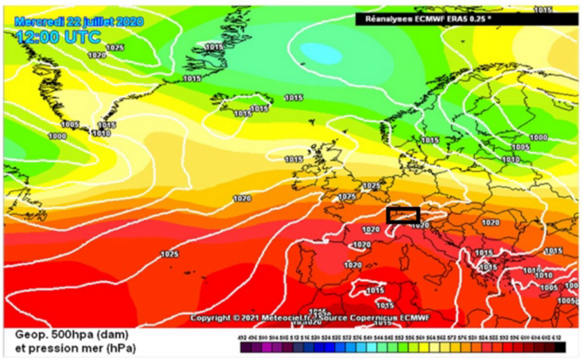

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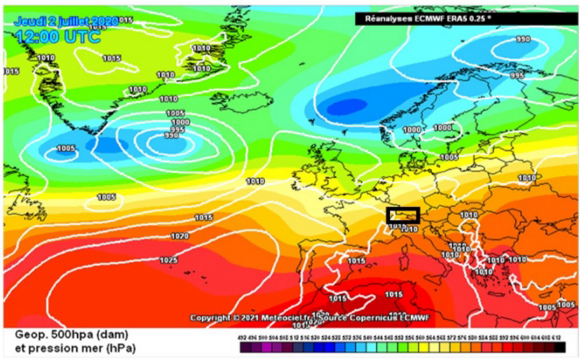

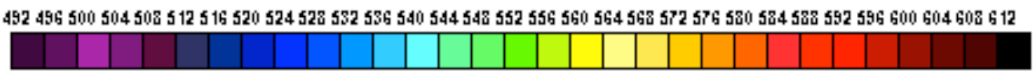

Figure S1) Synoptic situation for the eight cases, sorted by CAPE. Shown are the sea level pressure and geopotential height at the 500 hPa level at 12:00 UTC, based on ECMWF ERA5 reanalysis data. The black boxes indicate the areas where the 8 simulated convective storms occurred. The charts were obtained from Meteociel.fr.

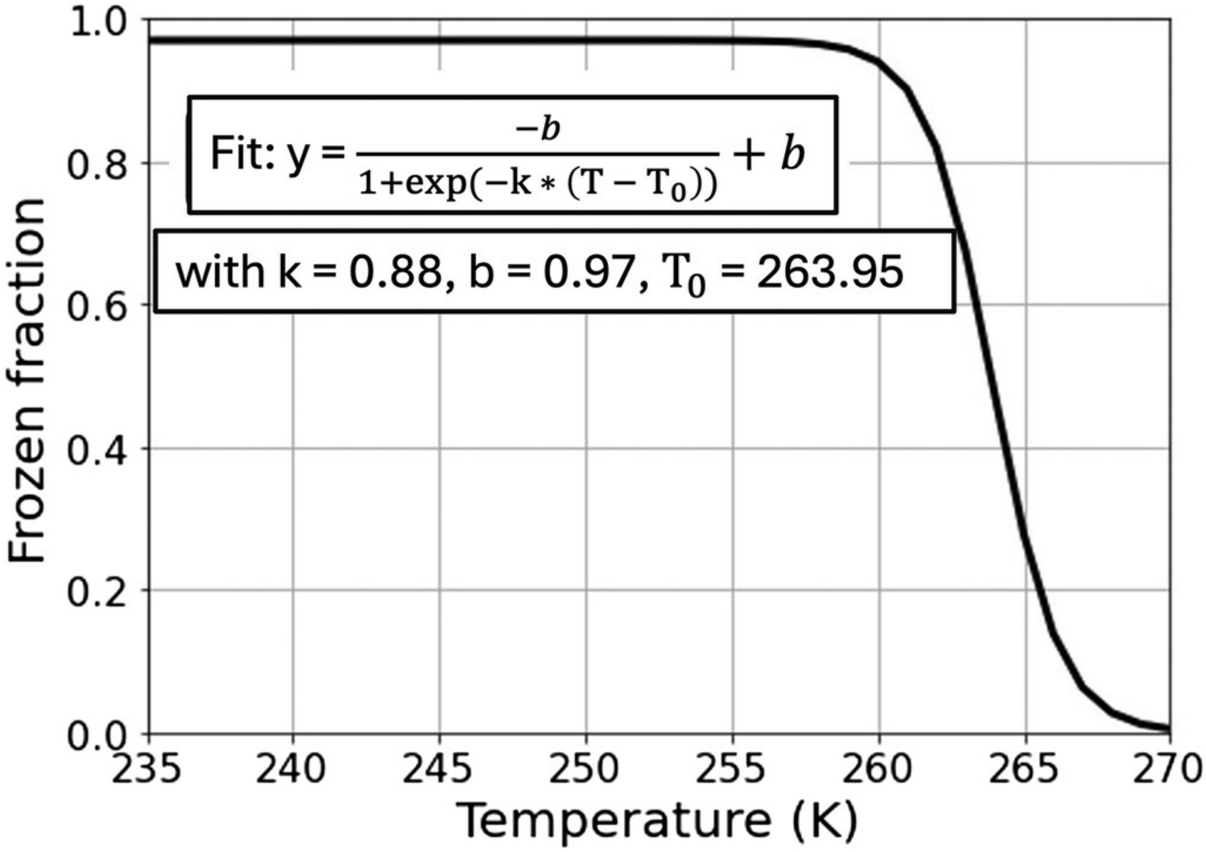

Figure S2) Frozen fraction as a function of temperature (K) for simulated AgI particles based on measurements from Marcolli et al. (2016). The above formula is valid for particles with a diameter of 400 nm.

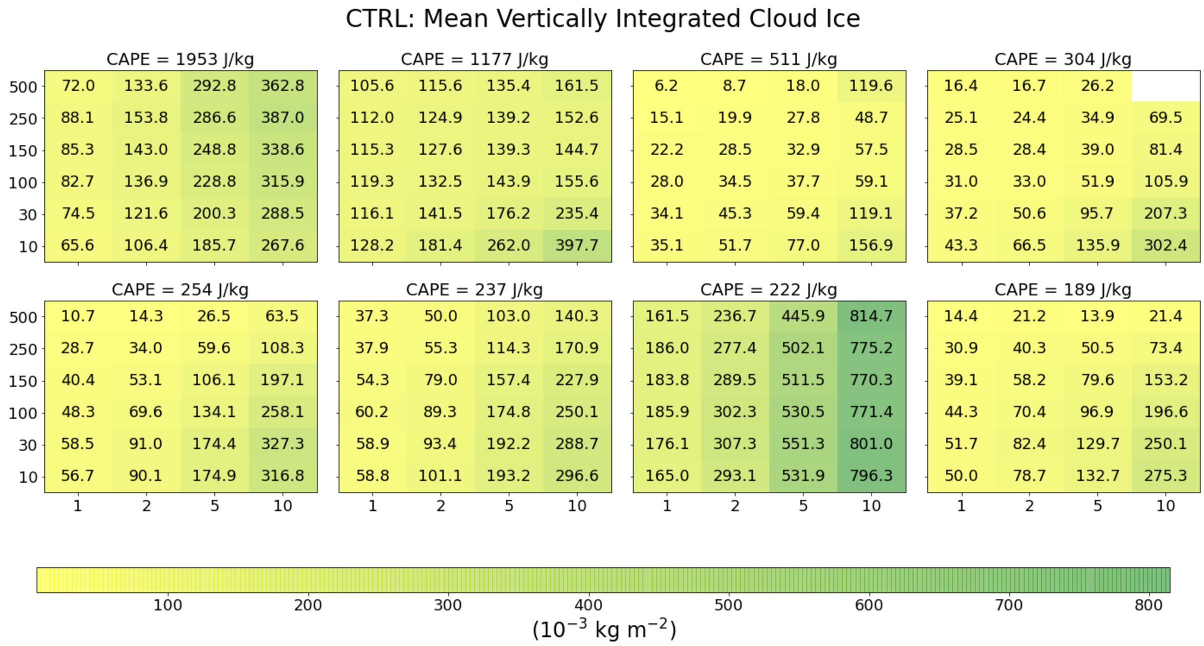

Figure S3) The CTRL panel of Figure 12 (manuscript).

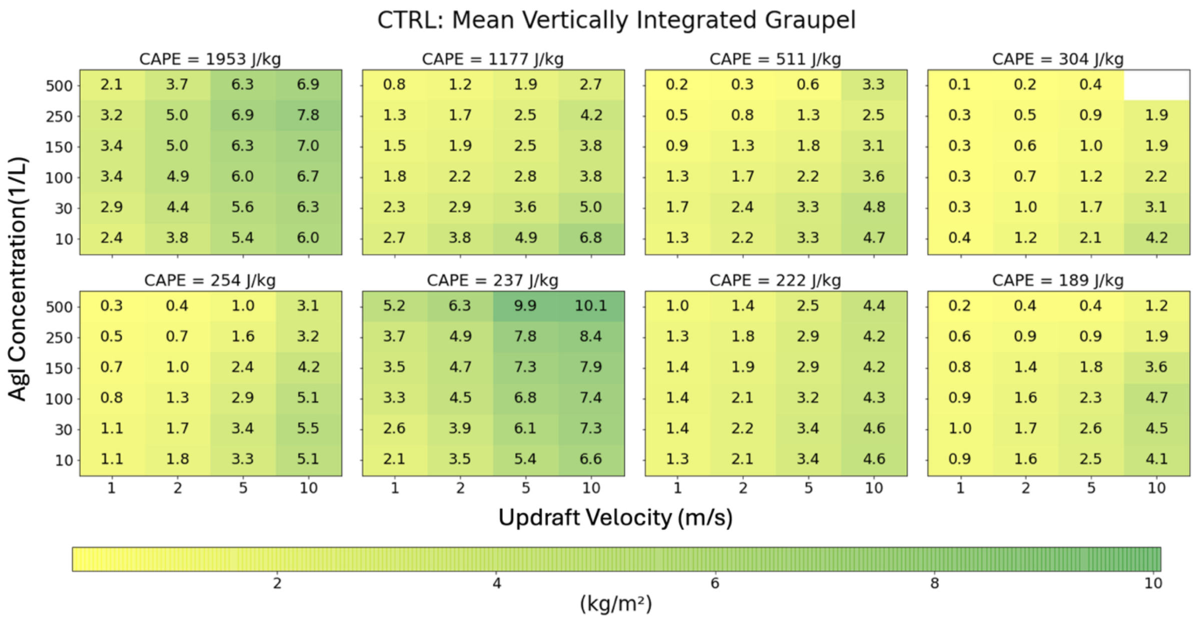

Figure S4) The CTRL panel of Figure 13 (manuscript).

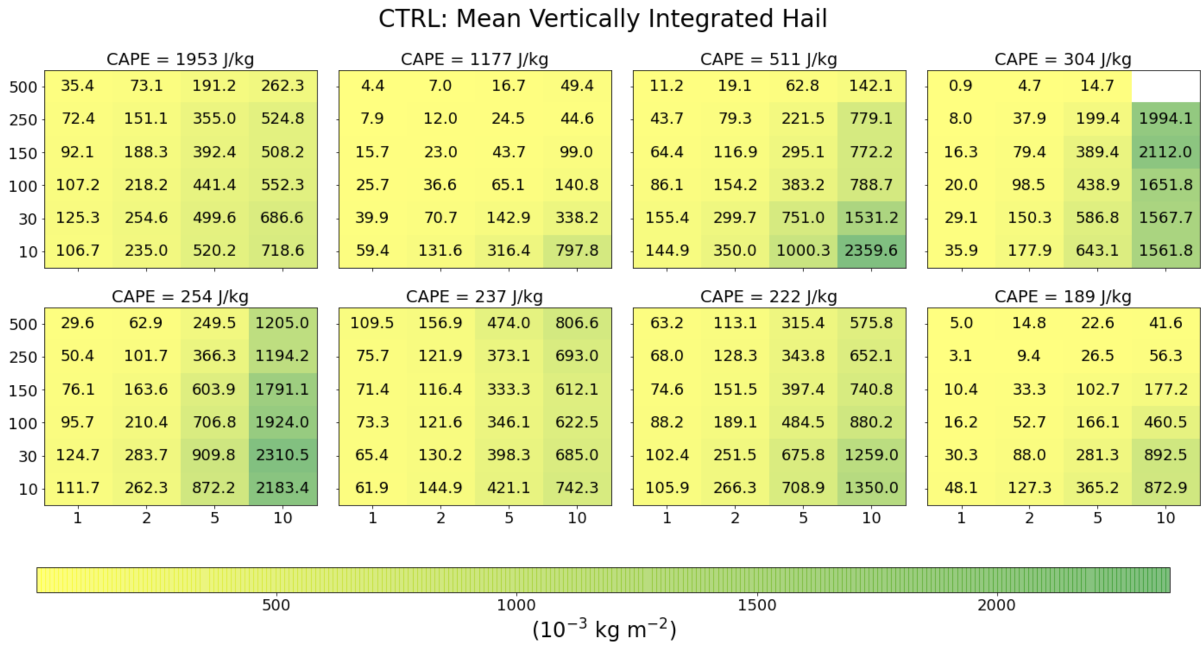

Figure S5) The CTRL panel of Figure 14 (manuscript).

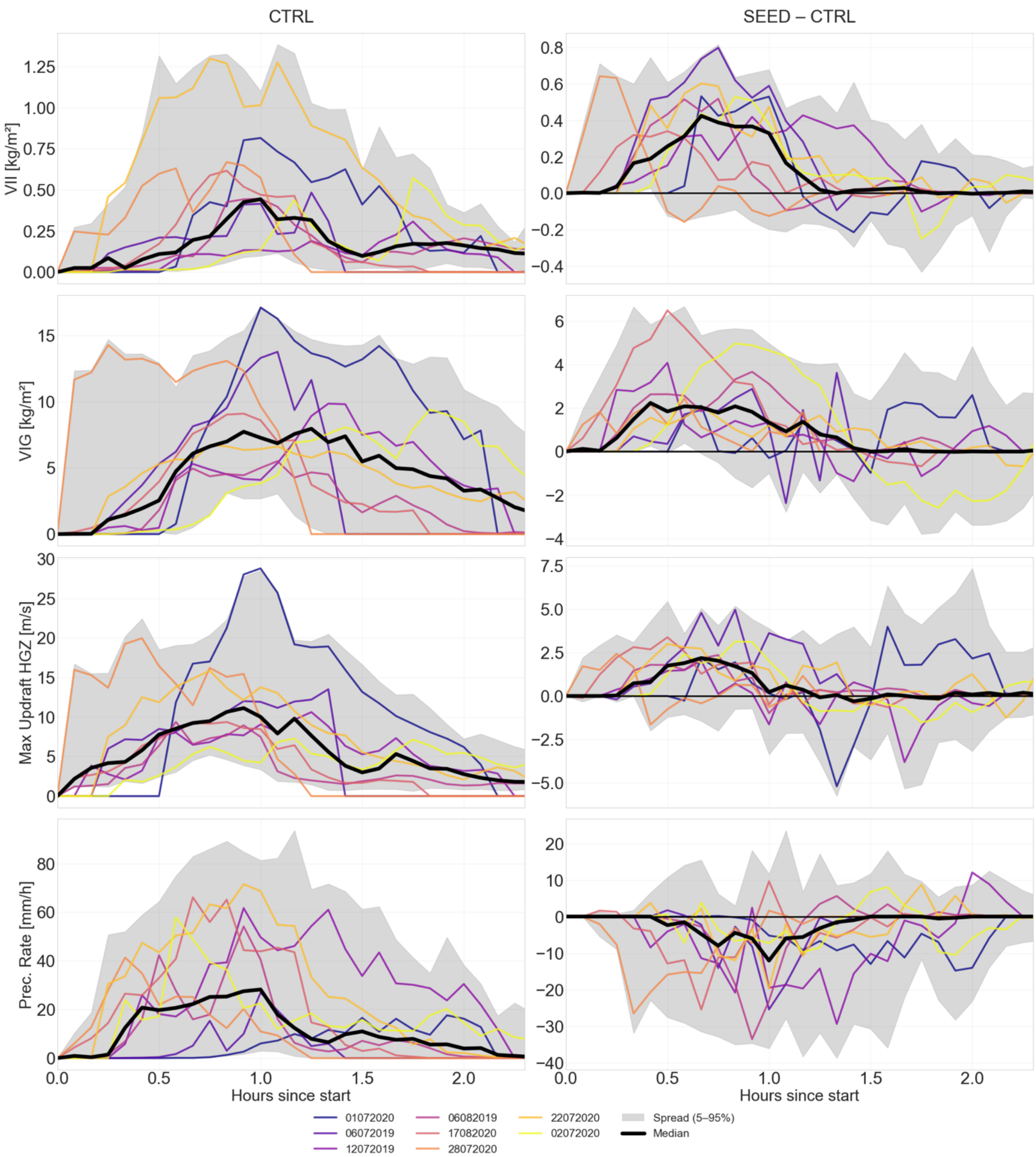

Figure S6) Time evolution of the 99th spatial percentile values for (top to bottom): vertically integrated ice (VII), vertically integrated graupel (VIG), maximum updraft velocity in the hail growth zone (-10°C to -30°C), and precipitation rate. The left column shows results from the CTRL simulations, while the right column shows the difference between SEED and CTRL simulations (SEED–CTRL). Colored lines represent ensemble means for individual cases, the black line denotes the median, and the shaded area indicates the 5th–95th percentile range among the 80 simulations in each category (CTRL or SEED). Tracking is based on AgI concentrations in the convective cloud greater than 150 L^{-1} and maximum updraft speeds within the grid column greater than 1 m s^{-1}.

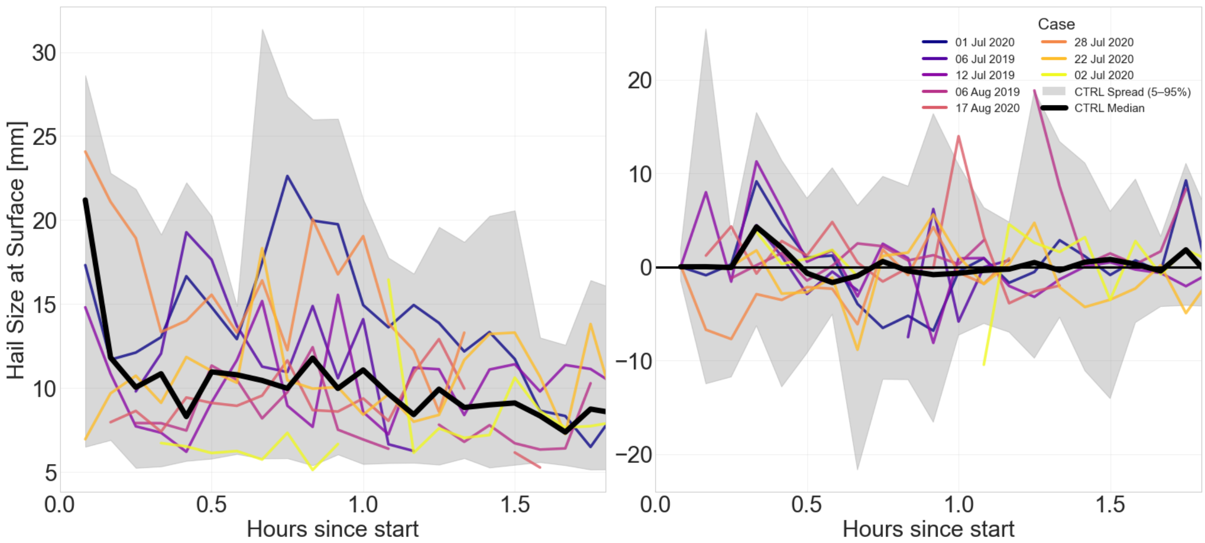

Figure S7) Same as the previous Figure S6, but showing the 99th spatial percentile of hail sizes at the surface.

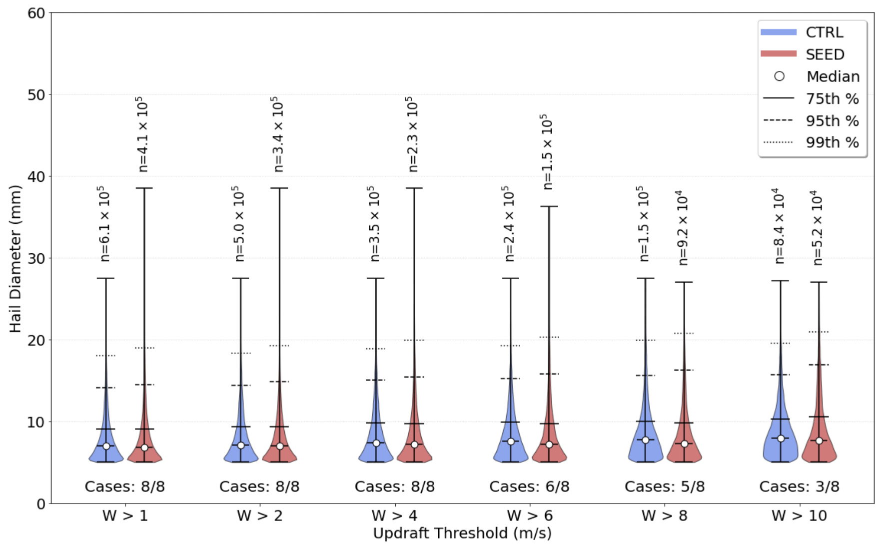

Figure S8) Violin plots comparing the distribution of hail diameters (mm) between control (CTRL, blue) and seeded (SEED, red) simulations across various updraft velocity thresholds (m/s). The outer bars of the violin plots represent the maximum value. Data are aggregated across all simulated cases, ensemble members, and grid points for the first 1.2 hours of tracking. White dots indicate the median hail size, n denotes the total number of data points for each distribution, and the labels at the bottom indicate the fraction of cases that reached each updraft threshold and produced hail.

Case	Start	End
01 jul 2020	15:35	17:10
06 Jul 2019	12:45	13:50
12 Jul 2019	10:50	12:55
06 Aug 2019	09:55	13:00
17 Aug 2020	13:45	15:30
28 Jul 2020	13:45	14:50
22 Jul 2020	14:45	17:30
02 Jul 2020	11:20	13:50

Table S1) The seeding period and the start and end times for the 8 simulated storm cases (in UTC). Seeding was applied for 10 minutes beginning at the storm start time.

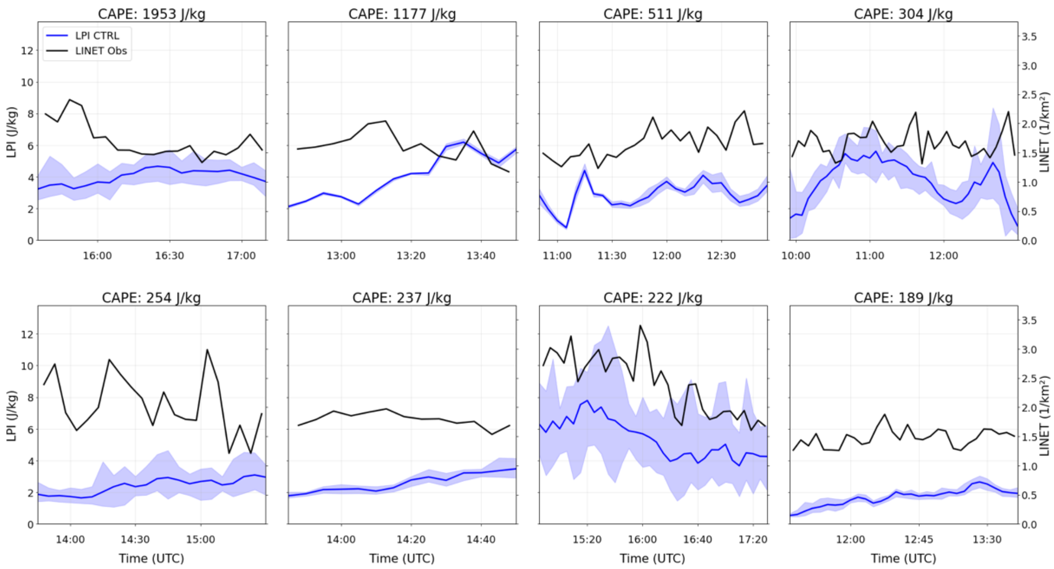

Figure S9) Comparison of the spatially averaged LPI (model) with the LINET (observations) lightning density over an analysis domain centered on the simulated thunderstorm for the eight convective cases, ranked by descending ensemble-mean CAPE. Blue lines represent the ensemble mean of the LPI CTRL experiments, with shaded areas indicating the ensemble spread. Black lines show the observed lightning density from the LINET network. To ensure a consistent comparison, both the LPI and LINET datasets were spatially averaged using a threshold of 0.1 to exclude non-convective regions. All cases are plotted on a standardized UTC time axis.

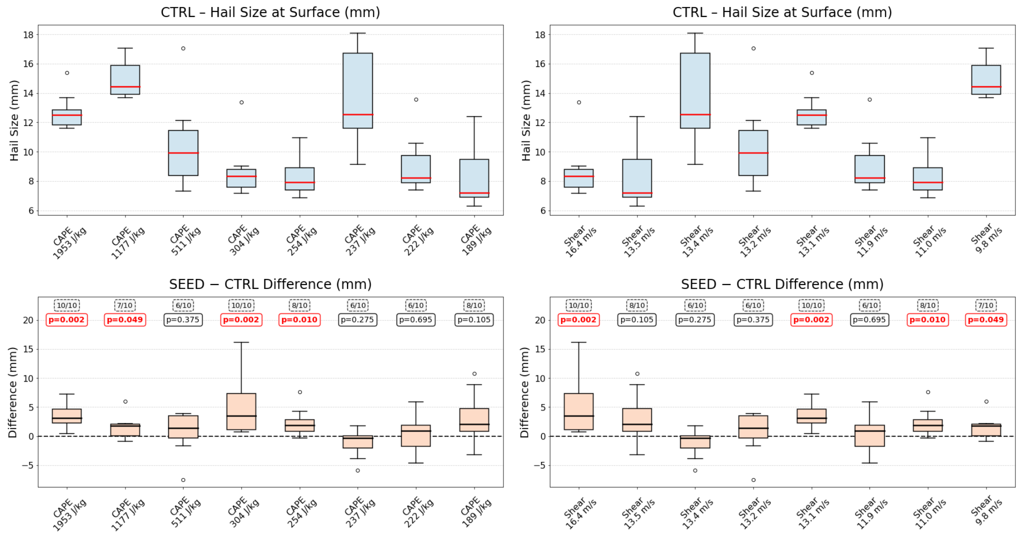

Figure S10) As in Figure 9 of the main manuscript, but displaying boxplots to show the full ensemble distribution (10 members per case) of surface hail size across all cases. Cases are sorted from left to right in descending order of environmental conditions: CAPE (left panels) and wind shear (right panels). Top panels (CTRL) show absolute surface hail sizes for unseeded simulations, denoted by blue boxes. Bottom panels (SEED - CTRL) illustrate the difference in surface hail size between seeded and unseeded simulations. The boxplots define the interquartile range (IQR), the horizontal line denotes the median, and the whiskers extend to the minimum and maximum values for each case's ensemble members. Additionally, p-values from the Wilcoxon signed-rank test are presented to compare each SEED case with its corresponding CTRL simulation. Finally, dashed boxes indicate the number of members (e.g., 8/10) that agree with the sign of the ensemble mean difference.

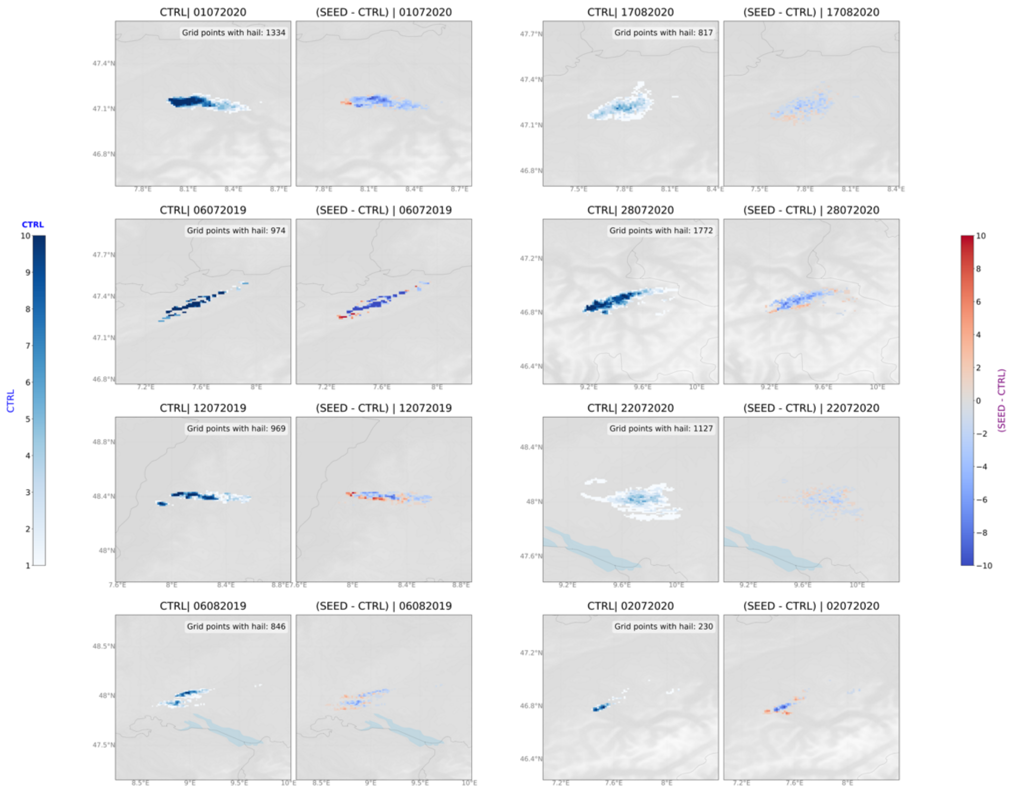

Figure S11) Spatial distribution of surface hail occurrence of the studied cases sorted by CAPE. The left column (blue) presents the CTRL, while the right column displays the difference (SEED - CTRL) for every case. The color intensity represents the number of ensemble members (out of 10) that simulated maximum surface hail exceeding the 5.0 mm threshold over the 1.2-hour analysis period. The total count of grid points satisfying this threshold for the CTRL is annotated in the upper right corner of the left panels. Background shading indicates the local topography. The lake depicted is Lake Constance.

		CTRL					SEED				
		n	Median	75th	95th	99th	n	Median	75th	95th	99th
W Threshold	Case		(mm)	(mm)	(mm)	(mm)		(mm)	(mm)	(mm)	(mm)
W > 1 m/s	01 Jul. 2020	2.0×10^{5}	7.2	8.9	12.8	16.8	9.3×10^{4}	7.1	9.4	15.8	20.4
	06 Jul. 2019	8.1×10^{4}	9.2	12.1	15.6	17.0	5.0×10^{4}	8.7	11.4	15.6	17.8
	12 Jul. 2019	3.3×10^{4}	5.9	6.9	10.1	14.5	3.5×10^{4}	6.3	7.9	13.5	18.5
	06 Aug. 2019	4.3×10^{4}	6.1	7.1	9.4	11.9	3.9×10^{4}	6.4	7.9	11.8	15.6
	17 Aug. 2020	3.7×10^{4}	6.0	7.1	9.6	12.8	2.5×10^{4}	6.1	7.7	13.7	19.8
	28 Jul. 2020	1.4×10^{5}	7.9	10.7	16.7	21.2	9.5×10^{4}	7.7	9.8	14.9	20.7
	22 Jul. 2020	7.0×10^{4}	6.1	7.1	9.9	13.4	6.6×10^{4}	6.0	7.1	10.7	15.6
	02 Jul. 2020	8.1×10^{3}	5.5	6.0	8.1	11.6	9.1×10^{3}	6.5	8.5	13.8	18.5
W > 10 m/s	01 Jul. 2020	4.9×10^{4}	8.2	10.0	14.1	18.2	2.9×10^{4}	8.2	11.6	17.7	21.7
	28 Jul. 2020	2.8×10^{4}	8.3	11.8	17.7	21.2	1.7×10^{4}	7.6	9.8	16.1	19.9
	22 Jul. 2020	6.8×10^{3}	6.3	7.2	9.3	12.2	5.0×10^{3}	5.8	6.8	10.4	14.8

Table S2) In contrast to the aggregated data shown in Figure S8, this table provides a case-by-case breakdown for updraft velocity thresholds of W > 1 m/s (baseline) and the highest one, W > 10 m/s. Cases are listed in descending order based on their CAPE. For each case and threshold, the total number of data points (n), the median hail size, and the 75th, 95th, and 99th percentiles are presented.