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Supplementary information

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Contrasting trends in very large hail events and related economic losses across the globe

In the format provided by the authors and unedited

Supplementary material

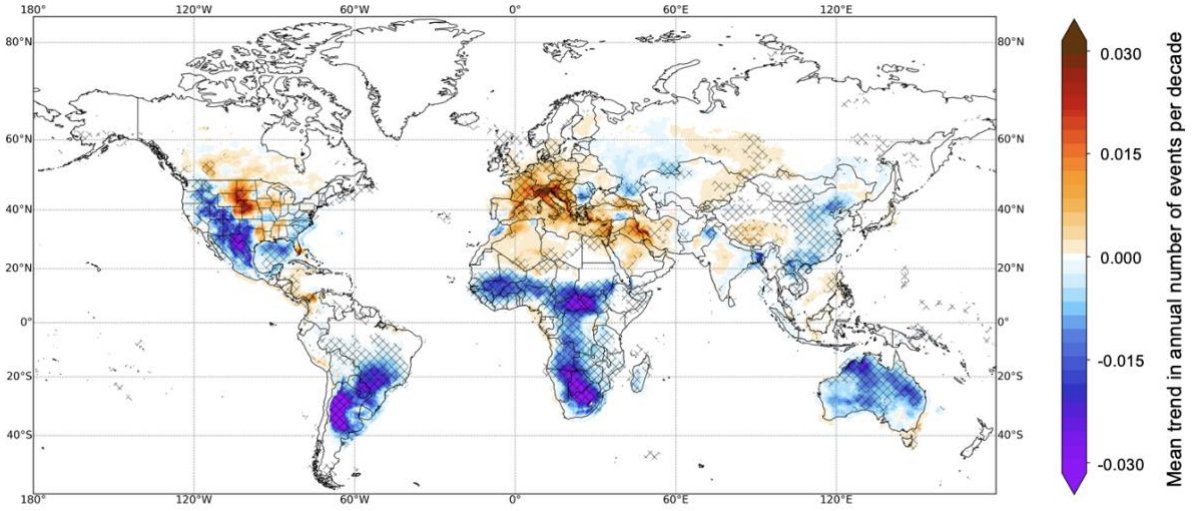

Fig. 1: Mean trend in annual number of VLH events per decade between 1979 and 2023. Trends significant at a 95 percent level are hatched.

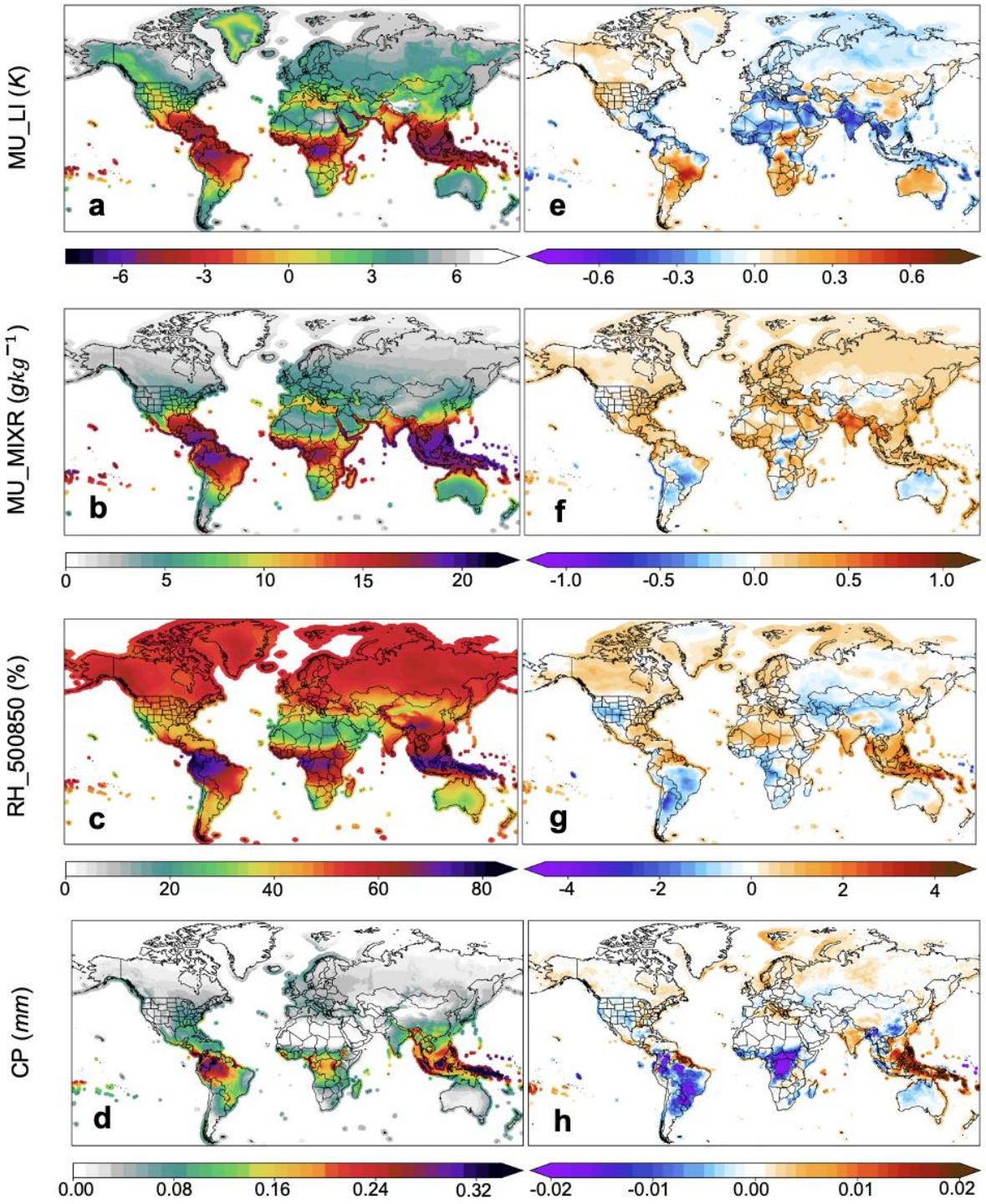

Fig. 2: Mean values and decadal trend in lightning model ($P_{lightning}$) predictors. From top to bottom: (a, e) Most Unstable Lifted Index (MU_LI), (b, f) Most Unstable Mixing Ratio (MU_MIXR), (c, g) Mean Relative Humidity between 500 and 850 hPa (RH_500850hPa), and (d, h) Convective Precipitation (CP).

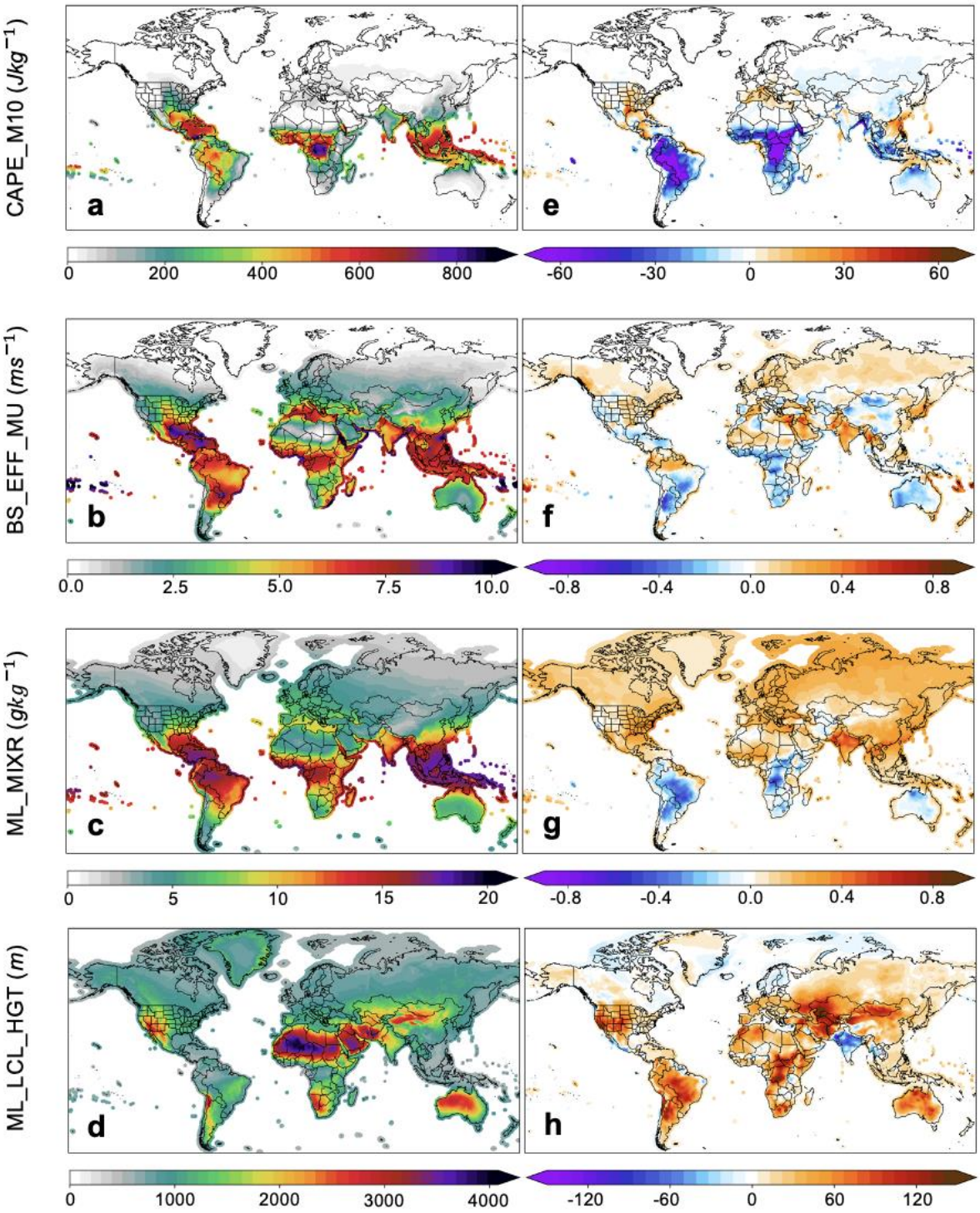

Fig. 3: Mean values and decadal trend in conditional VLH model ($P_{VLH|lightning}$) predictors. From top to bottom: (a, e) Most Unstable CAPE above the -10°C isotherm (CAPE_M10), (b, f) Effective Most Unstable Bulk Shear (BS_EFF_MU), (c, g) Mixed Layer Mixing Ratio (ML_MIXR), and (d, h) Mixed Layer Lifting Condensation Height (ML_LCL_HGT).

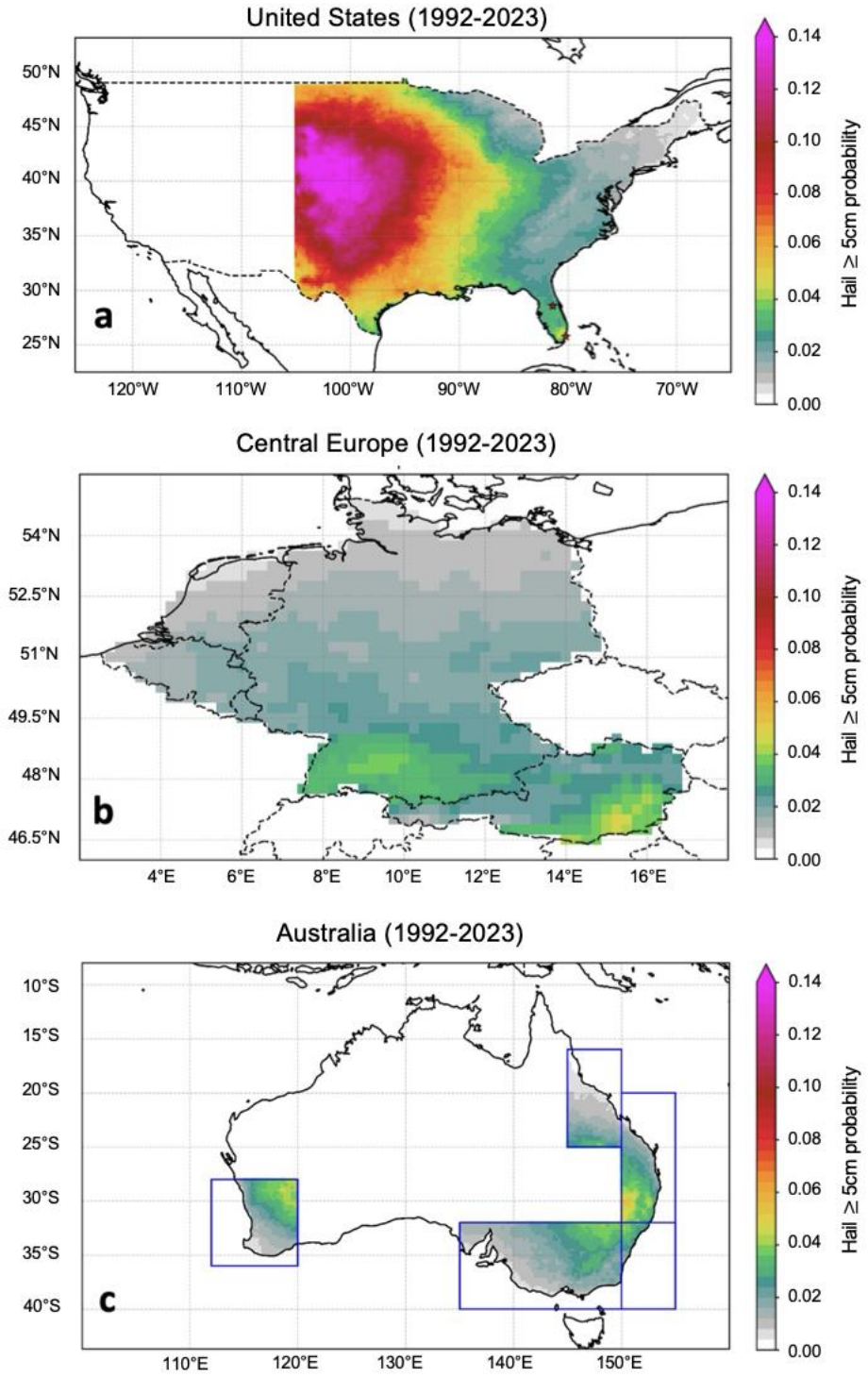

Fig. 4: Areas considered for the comparison of trends in VLH frequency and those in hail loss events. The mean annual number (1950-2023) of VLH events is shown for the areas considered across (a) the United States, (b) Europe, and (c) Australia.

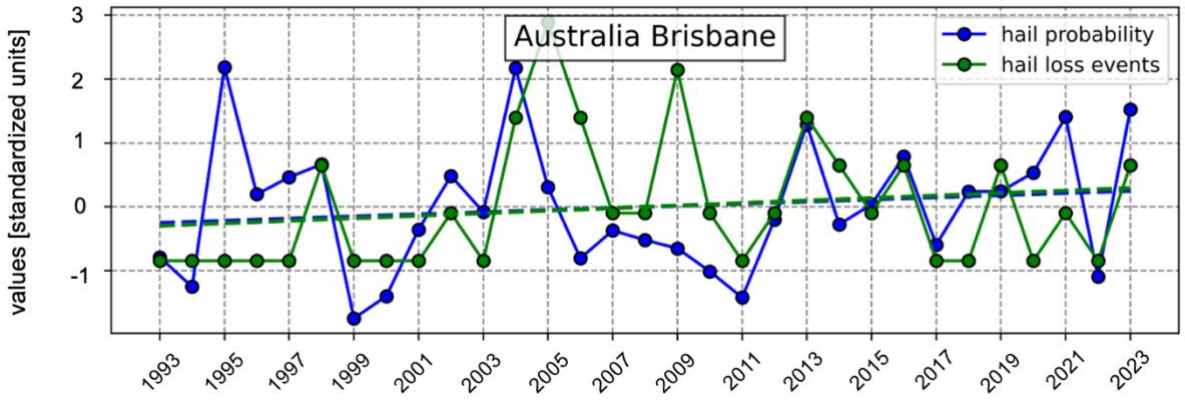

Fig. 5: Time series of the standardized mean annual sum of VLH probabilities (blue line) and hail loss events (green line) for Brisbane (latitude: -27.25° to -27.75°, longitude 152.75° to 153.25°).

Model	**Predictor acronym**	**Predictor name**	**Physical meaning**
$P_{lightning}$	MU_LI	Most Unstable Lifted Index	Instability
	RH_500850hPa	Mean Relative Humidity 500-850 hPa	Mid-level humidity
	MU_MIXR	Most Unstable Mixing Ratio	Low-level humidity
	CP	Convective Precipitation	Convective Precipitation
	LSM	Land Sea Mask	Land Sea Mask
$P_{VLH\|lightning}$	MU_500_CAPE_M10	Most Unstable CAPE above -10°C	Instability high up in the storm
	BS_EFF_MU	Effective Most Unstable Shear	Vertical wind shear
	ML_MIXR	Mixed Layer Mixing Ratio	Low-level humidity
	ML_LCL	Lifting Condensation Level	Height of cloud base

Table 1: List of predictors names for the VLH model, their acronym, and the corresponding physical meaning. Parameters are distinguished between the ones used for the lightning model ($P_{lightning}$) and for the conditional VLH model ($P_{VLH|lightning}$).

Quantitative trends attribution

We calculated the relative contribution of each predictor (see Table 2) on the detected changes in VLH frequency in two regions: one in northern Italy (45.0°–46.0°N, 8.50°W–9.50°E) and the other in northwestern Argentina (32.0°–33.0°S, 68.0°–69.0°W). The procedure to calculate the contribution of each predictor is the following:

1. *Calculate predictor mean and trends*: We calculated the area-averaged mean and trend between 1950 and 2023 of each predictor when the 99th percentile of VLH probability was met. Using the 99th percentile of VLH probability allowed us to focus on the conditions when VLH was most likely to happen.
2. *Calculating the relative contributions:* Take CAPE_M10 as an example predictor of the VLH model:
    a. We determined the relative (%) change in VLH probability resulting from a 1 J/kg increase in CAPE_M10 by taking the partial derivative of VLH probability with respect to CAPE_M10. We did so while keeping the other predictors at the respective values identified in step 1, to ensure we focus on the predictor's contribution only when the background conditions were favorable to VLH.
    b. We multiplied the relative (%) change from step 2a by the overall CAPE_M10 detected trend (step 1) to estimate how the overall change (1950-2023) in that predictor's value affected the VLH probability throughout the 74-year period.
3. *Extend to all predictors:*
    a. We repeated step 2 for all predictors of the VLH model (BS_EFF_MU, ML_MIXR, ML_LCL_HGT).
    b. We did the same for the predictors of the lightning model (MU_LI, RH_500850, MU_MIXR, CP), taking the partial derivative of lightning probability instead of VLH probability.

$P_{lightning}$					
	MU_LI	**RH_500850hPa**	**MU_MIXR**	**CP**	**TOTAL**
Northern Italy	+10.0%	-5.1%	-7.2%	-4.0%	-6.3%
Western Argentina	+7.3%	-20.1%	-0.9%	+2.2%	-15.9%
$P_{VLH\|lightning}$					
	MU_CAPE_M10	**BS_EFF_MU**	**ML_MIXR**	**ML_LCL**	**TOTAL**
Northern Italy	+55.7%	+5.9%	-14.1%	+31.6%	+79.1%
Western Argentina	-44.5%	+5.7%	+10.8%	+19.4%	-8.6%

Table 2: List of predictors' contributions to the lightning model $P_{lightning}$ and the conditional VLH model ($P_{VLH|lightning}$) across northern Italy and western Argentina.