EGU25

Future changes in the occurrence of large hail events in the Mediterranean region

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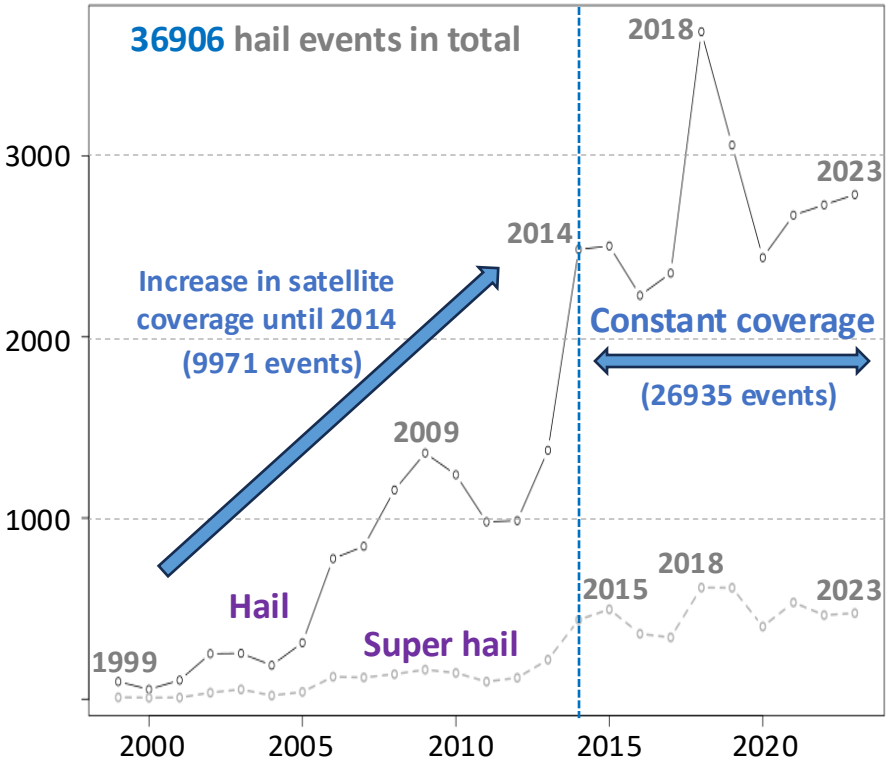
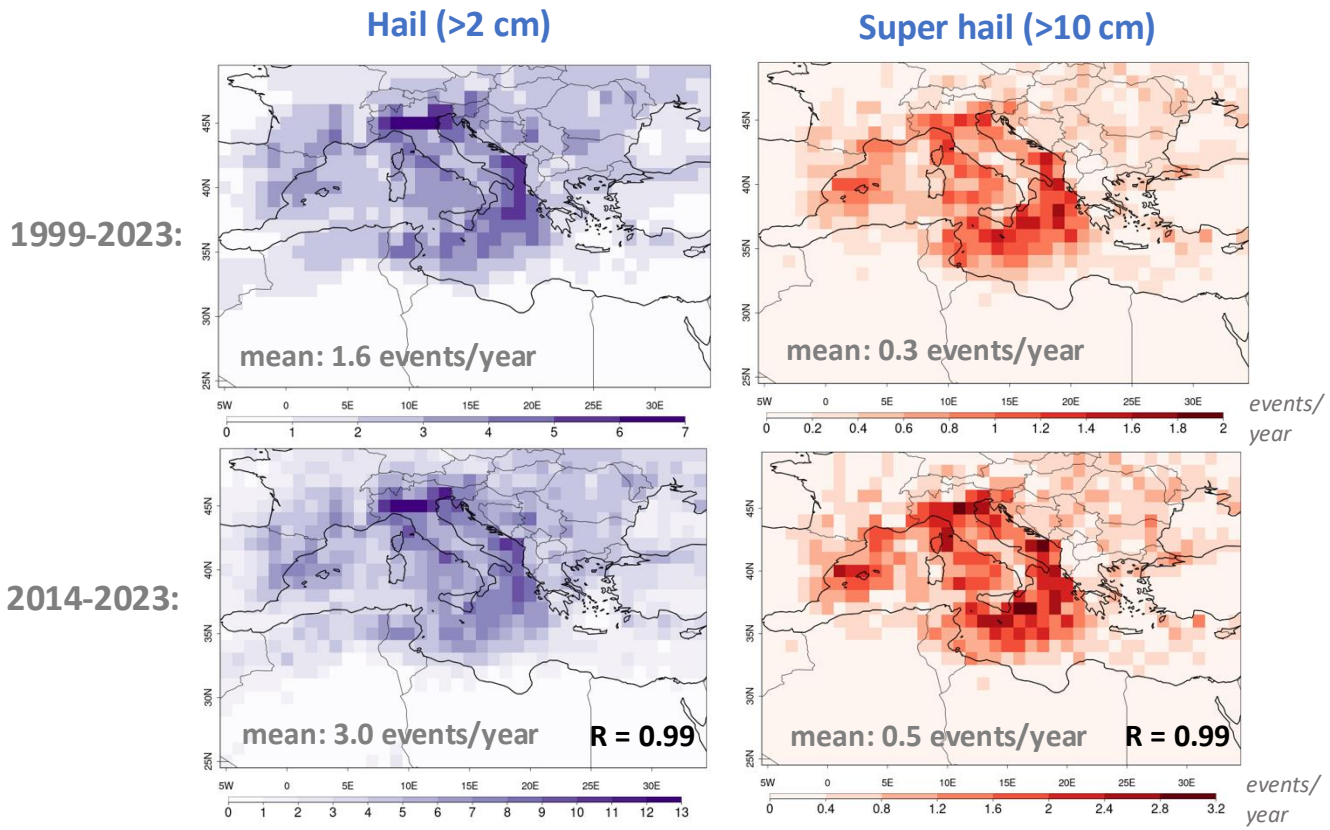
New 25-years hail dataset by Laviola et al. 2022

Total number of hail events per year 1999-2023



Average yearly number of observed hail events



Region: ***Mediterranean [5°W-25°E, 25°N-50°N]***
Spatial resolution: ***1°*** *Temporal resolution:* ***3-hourly***
Years: ***1999-2023*** *Months:* ***April to November***

Predictor data

Reanaysis:

- ***ERA5*** (1999-2023) of 5 variables: ***Temperature, Geopotential, Relative Humidity, u- and v-components of wind*** at ***21 pressure levels*** between 0 and 250 hPa. Original resolution of 0.25° and hourly time step, interpolated to the same grid and resolution of the hail dataset (1° and 3-hourly time step)

GCMs:

- Multi-model of ***9 CMIP6*** simulations (2076-2100) at ***5 pressure levels: 250, 500, 700, 850*** and ***1000 hPa***. One simulation per model (r1p1f1 run):
  - *BCC-CSM2-MR*
  - *CMCC-CM2-SR5*
  - *CMCC-CM2-HR*
  - *EC-Earth3*
  - *FGOALS-f3-L*
  - *INM-CM5-0*
  - *MPI-ESM1-2-HR*
  - *Nor-ESM2-MM*
  - *TaiESM1*

Only the above 9 models satisfy these conditions:

1. **Daily data**
2. Spatial resolution of **100 km or better**
3. 5 pressure levels variables: **relative humidity,** geopotential, temperature, u- and v-component of wind
4. The following 4 socioeconomic pathways: ***SSP1 2.6, SSP2 4.5, SSP3 7.0*** and ***SSP5 8.5***

240 hail predictors grouped in:

#31: Wind shear at various levels
#25: Temperature-based indices
#22: CAPE and derived indices (e.g: MUCAPE)
#12: Storm-relative helicity at various levels
#14: Temperature lapse rate at various levels
#13: Relative humidity at various levels
#8: Lifted index and derived indices
#6: Wind speed at various levels
#5: Geopotential height at various levels
#104: other predictors

Only *84 of them* can also be defined for future climate using ***daily CMIP6*** data. Between the excluded predictors are ***CAPE***, ***MUCAPE*** and ***storm-relative helicity***. Some of the 84 included predictors are:

Mean relative humidity in the hail growth layer, K-Index, TotalTotals Index, SWEAT Index, Wind Index, Height of Freezing Level, Lifted Index, Temp. of the level of free convection, Precipitable water, Geopotential at 250-500-700-850-1000 hPa, Temp. difference with previous time step.

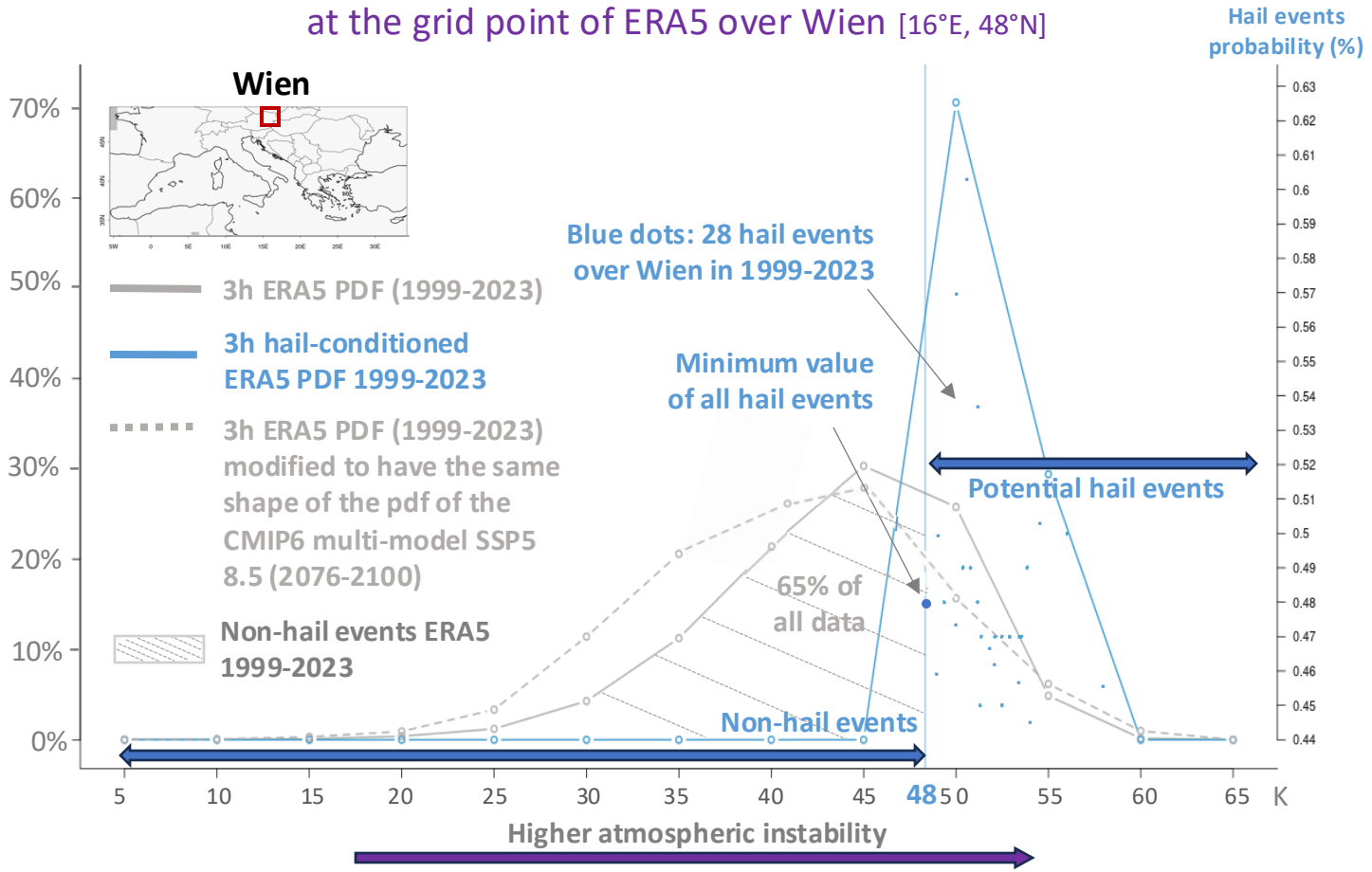
Full list of predictors at:
https://cran.r-project.org/web/packages/thunder/vignettes/convective-parameters-and-technical-details.html

RCMs were not considered, as resolution of hail dataset is coarser (1°)

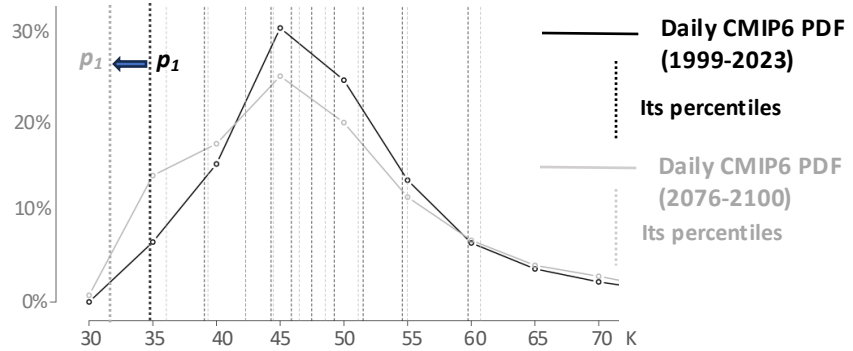
General idea: model the frequency of non-hail events

3-hourly PDF of TotalTotals Index $[TT = T_{850} + T_{Dew,\,850} - 2T_{500}]$

at the grid point of ERA5 over Wien [16°E, 48°N]



Daily PDF of TotalTotals for CMIP6 multi-model (SSP5 8.5)



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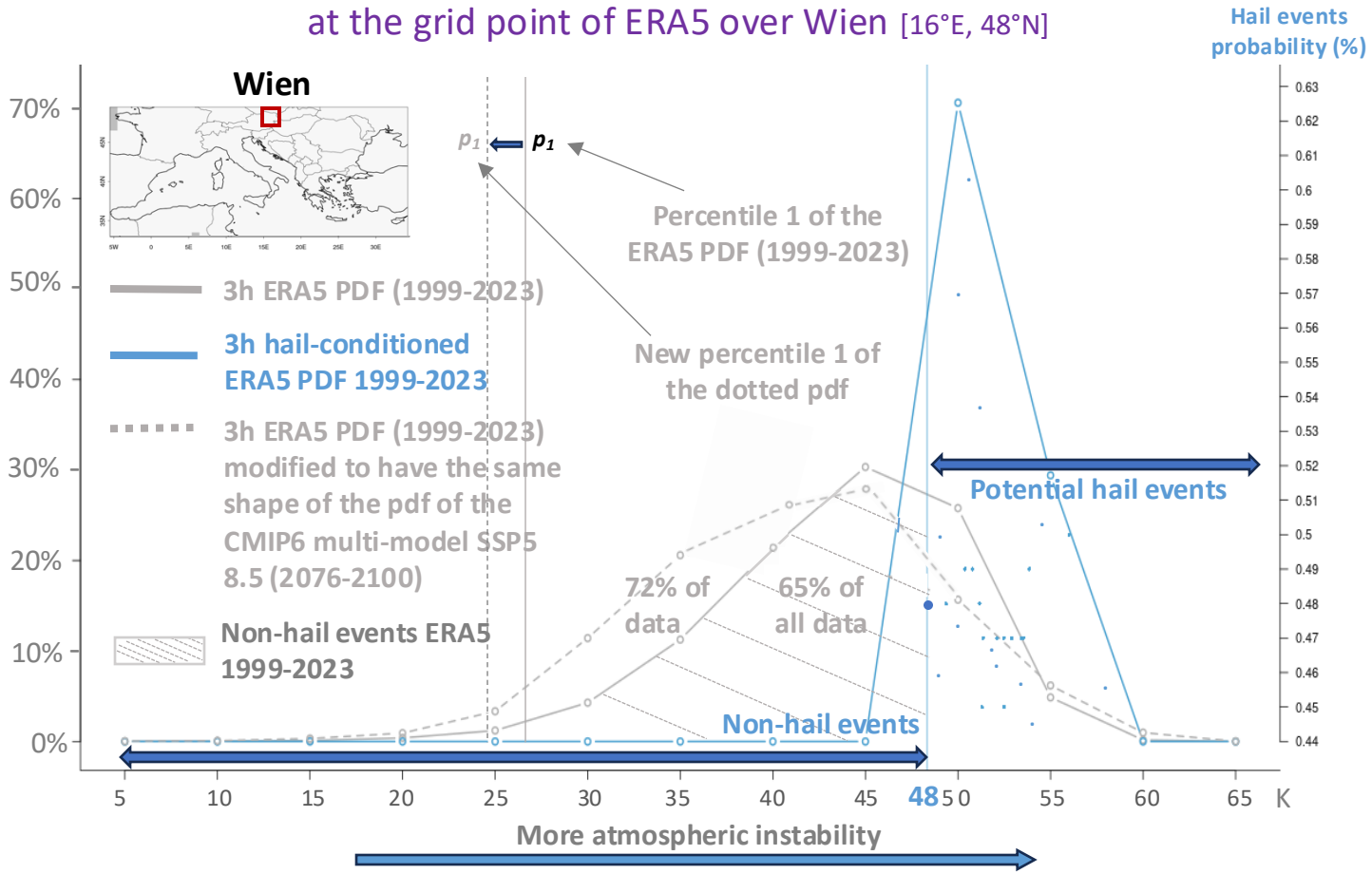
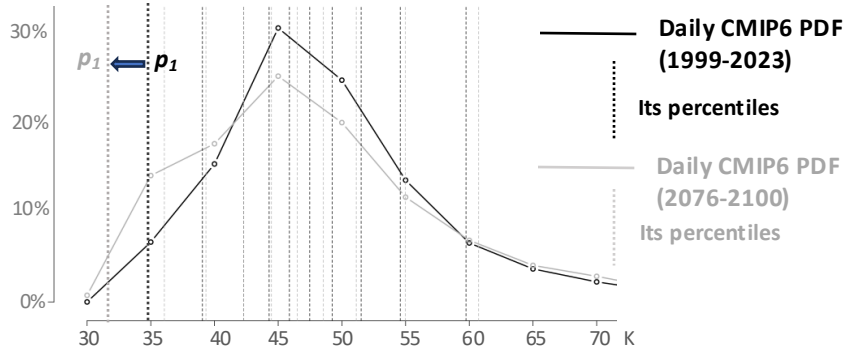


Daily PDF of TotalTotals for CMIP6 multi-model (SSP5 8.5)



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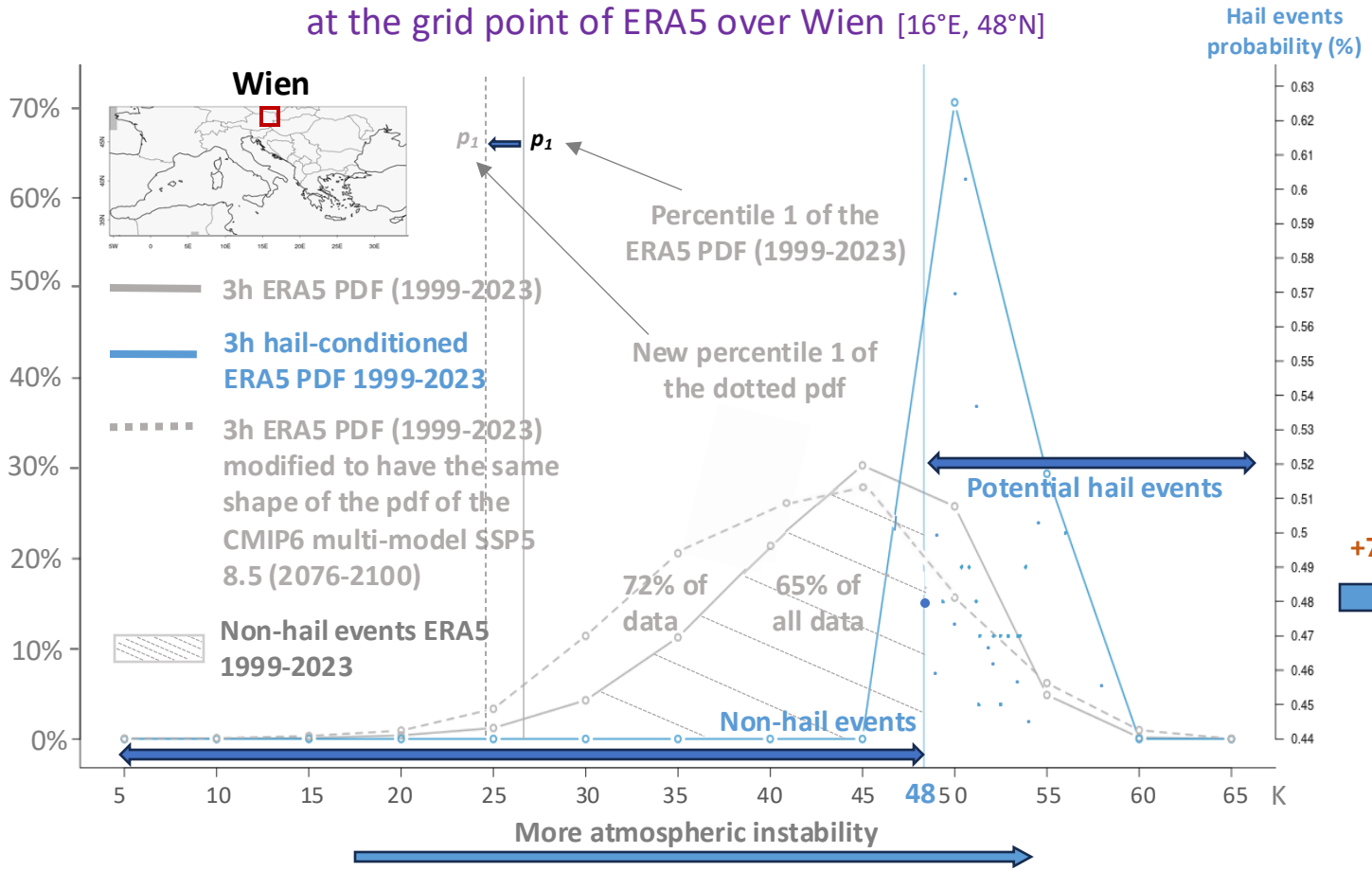
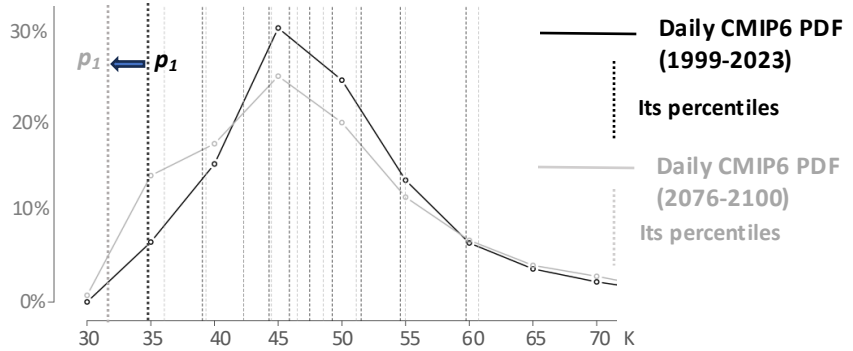


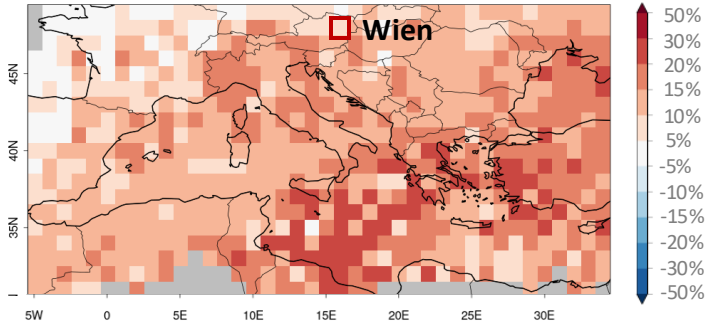
+7%

Daily PDF of TotalTotals for CMIP6 multi-model (SSP5 8.5)



Multi-model frequency change of non-hail events

(2076-2100 minus 1999-2023, SSP5 8.5)



Gray points: not enough hail data (<10 events/point)

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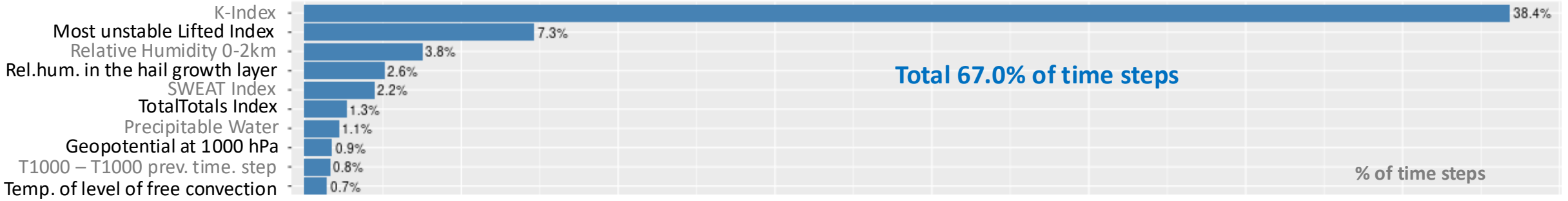
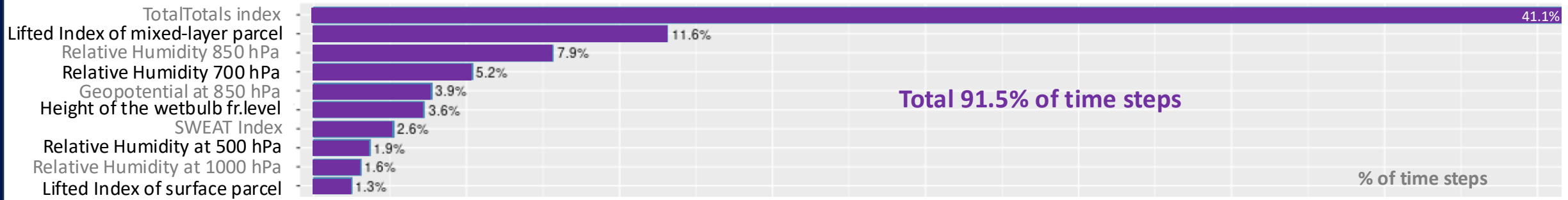
10 best predictors of non-hail events

Best predictors for ERA5 (1999-2023) considering all grid points in the Mediterranean



Best predictors for CMIP6 multi-model SSP5 8.5 (2076-2100) considering all grid points



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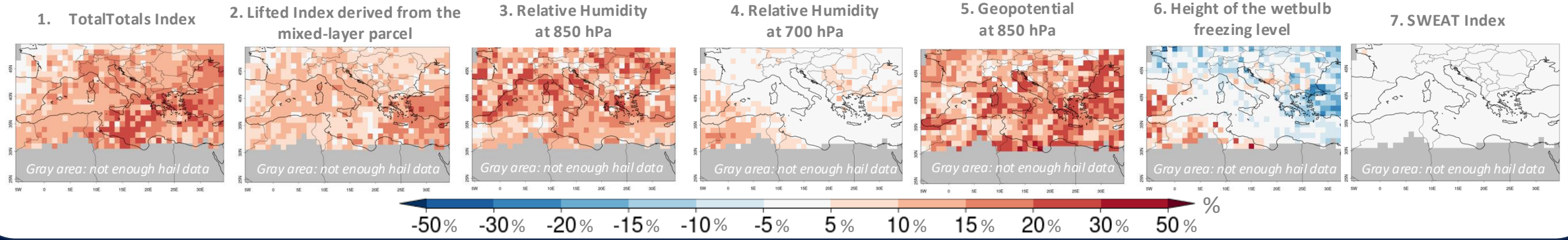
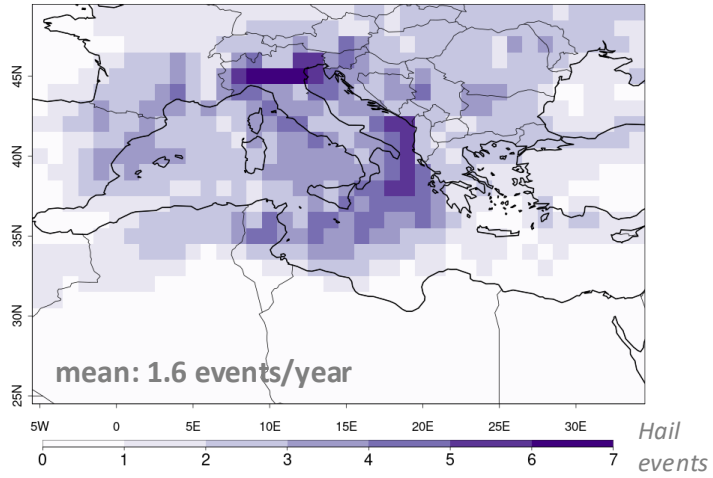


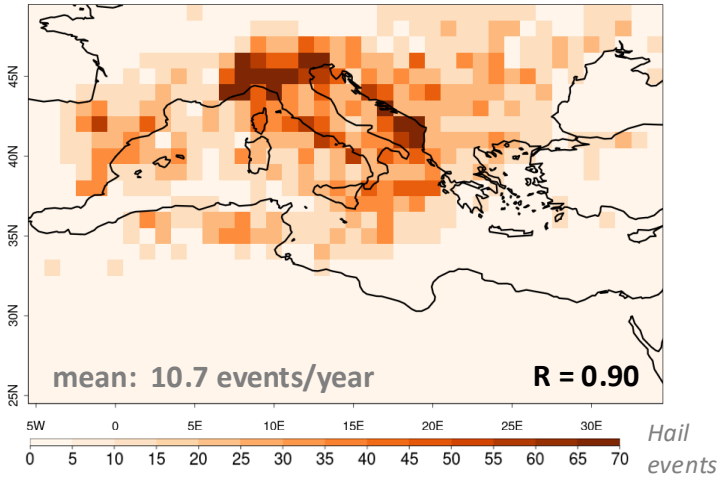
Validation of potential hail events 1999-2023

Average yearly number of obs. hail events

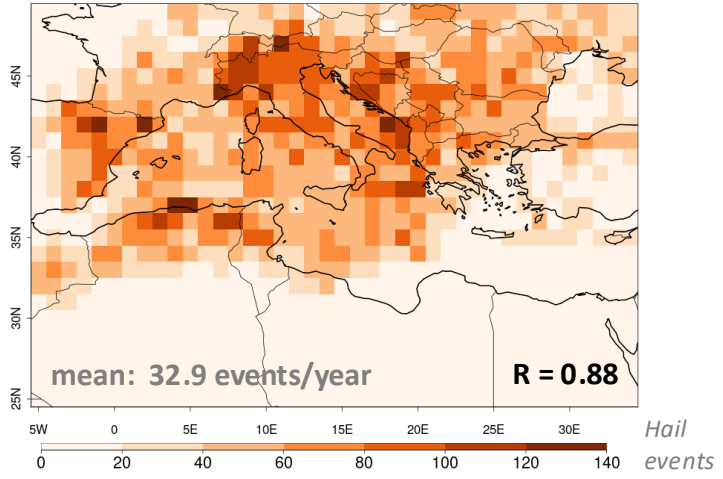


Average yearly number of *potential hail events*

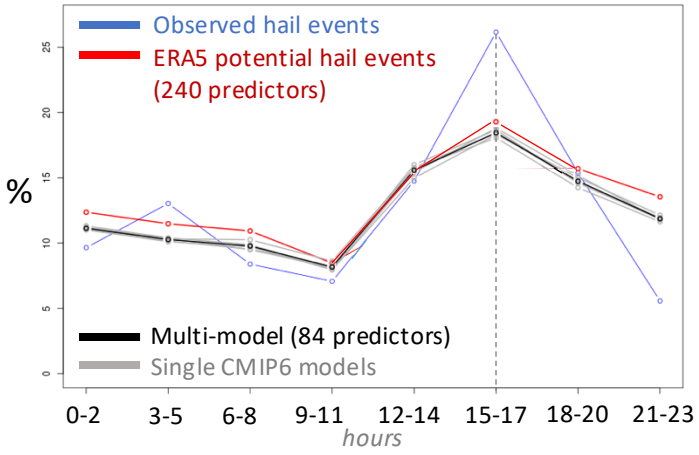
Estimated by 240 predictors ERA5



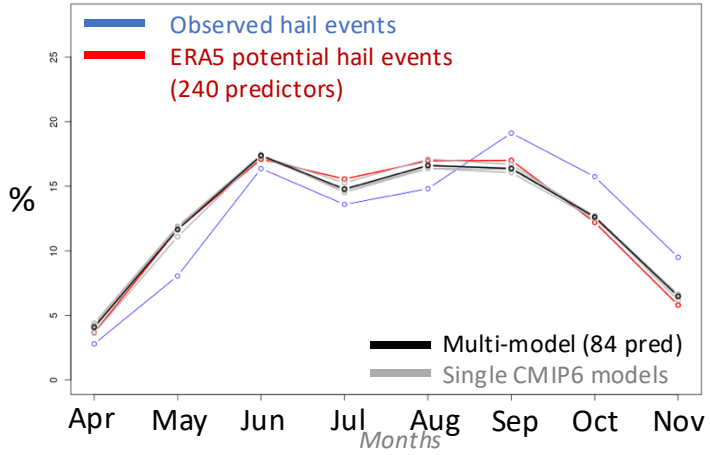
Estimated by 84 predictors Multi-model



Daily distribution of potential events



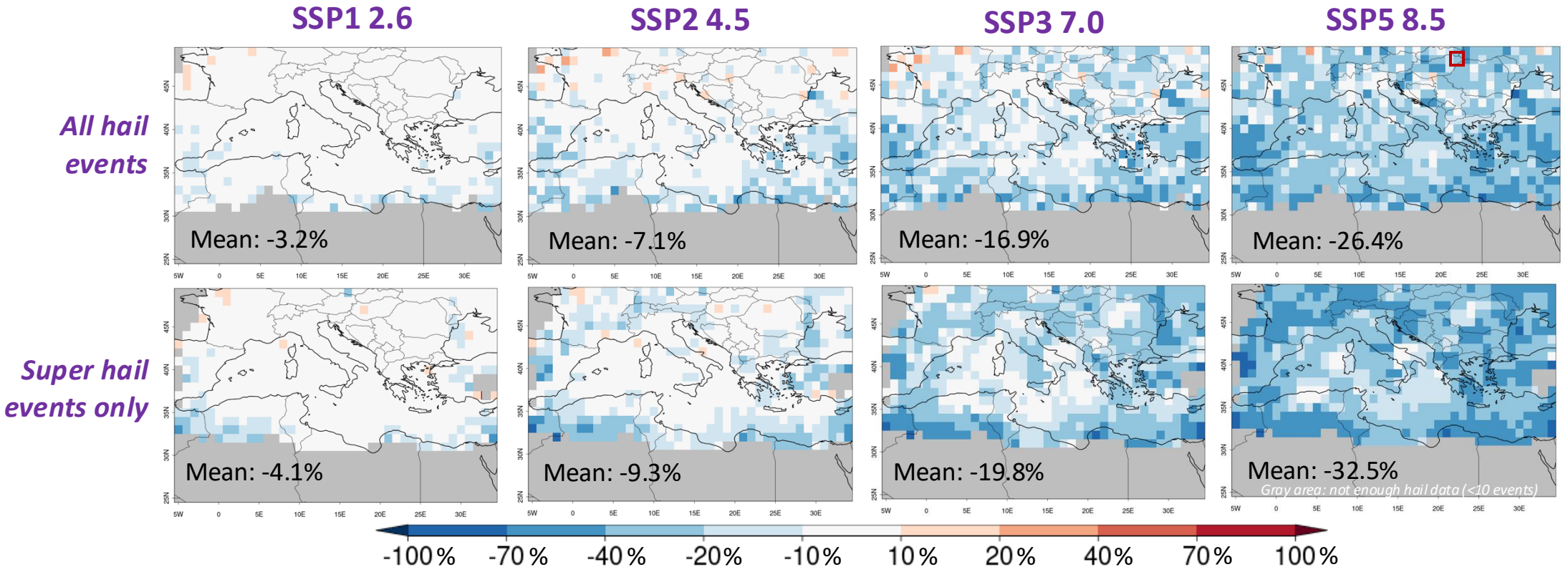
Monthly distribution of potential events



Both spatial and temporal distributions of the potential hail events are similar to that of the observed hail climatology

year

Multi-model % change of potential hail events (2076-2100 vs 1999-2023)



The multi-model predicts a ***decrease*** of the frequencies of both potential hail and potential superhail events the Mediterranean basin for ***SSP3 7.0*** and ***SSP5 8.5***, as a consequence of the increase of the frequencies of non-hail events.

However, the frequency of hail or superhail events ***might even increase***: the multi-model in fact ***doesn't estimate*** the changes of the probability of hail/superhail events within the class of potential hail/superhail events. It just estimates the ***maximum number*** of hail/superhail events.

Multi-model % change of potential hail events (2076-2100 vs 1999-2023)

All hail events

Super hail events only

5

data (<10 events)

The multi-model pre… …lediterranean basin for ***SSP3 7.0*** a…

However, the freque… …the changes of the probability of ha… …***ximum number*** of hail/superhail events.

Conclusions

- The ***84 predictors*** identified are a good proxy of ***non-hail events***, particularly the ***K-Index*** for present climate (1999-2023) and the ***TotalTotals Index*** for future climate (2076-2100)
- The multi-model of 9 CMIP6 simulations predicts a ***frequency increase*** in the Mediterranean of both ***non-hail and non-superhail events*** of up to 50%, particularly in Spain, Turkey, Austria, France, Italy and Greece
- The reason is meanly due to the well-known CMIP6 projected ***decrease of relative humidity*** at low levels (mostly at 850 hPa) over the Mediterranean in summer, that influences all hail predictors that depends on humidity, increasing the number of non-hail events
- To better constrain the number of non-hail events, ***hourly*** or ***3-hourly GCMs/RCMs*** would be needed. In this way, ***all 240 predictors*** could be employed. Also having more ***pressure levels*** than the 5 available below 250 hPa in CMIP6 simulations would greatly improve the vertical interpolation of many predictors.


Thank you!
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