Future projections of freezing rain climatology in Europe

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Matti Kämäräinen, Andrea Vajda, Otto Hyvärinen, Ilari Lehtonen, and Kirsti Jylhä
matti.kamarainen@fmi.fi

1 Introduction

Freezing rain (FZRA) is a potentially high-impact weather phenomenon. In this work, future estimations of FZRA occurrence were calculated based on an ensemble of six **EURO-CORDEX** regional climate models (RCMs) with **RCP4.5** and **RCP8.5** emission scenarios. A precipitation typing algorithm was applied to RCM data to identify FZRA. The occurrence of FZRA events above **5 mm/day** and **25 mm/day** impact thresholds were then evaluated. Finally the changes in annual probabilities of FZRA were calculated between the baseline and future periods.

2 Materials and methods

RCM data from six RCMs were used in this study (Tables 1, 2). FZRA events were identified following the methodology of Kämäräinen et al. [2016]. The method identifies the traditional FZRA formation mechanism, which requires the simultaneous occurrence of (1) a near-surface cold layer, (2) a melting layer above the cold layer, and (3) precipitation. The impact threshold values, **5 mm/day** and **25 mm/day**, were selected based on needs of critical infrastructure (Vajda et al. [2015]).

Table 1: Regional modelling institutes (columns) versus driving general circulation models (rows).

	SMHI	MPI-CSC	KNMI
EC-Earth			X
HadGEM2-ES			X
CanESM2	X		
MPI-M-LR		X	
IPSL-CM5A-MR	X		
NorESM1-M	X		

Table 2: Description of the dimensions and variables of the study.

Property	Value(s)
Spat. coverage	Europe
Time res.	6H
Spatial res.	0.44°
Levels	Sfc, 925, 850, 700
Scenarios	RCP4.5, RCP8.5
Periods	1971–2000, 2021–2050, 2071–2100
Variables	T, RH, Pr, p_{sfc}

3a Present-day climate

Compared to previous studies (Kämäräinen et al. [2016]), the multi-model mean of this work produces a similar spatial distribution of climatological monthly mean number of FZRA events in Europe. As an example, the result from one model can be seen in Fig. 1.

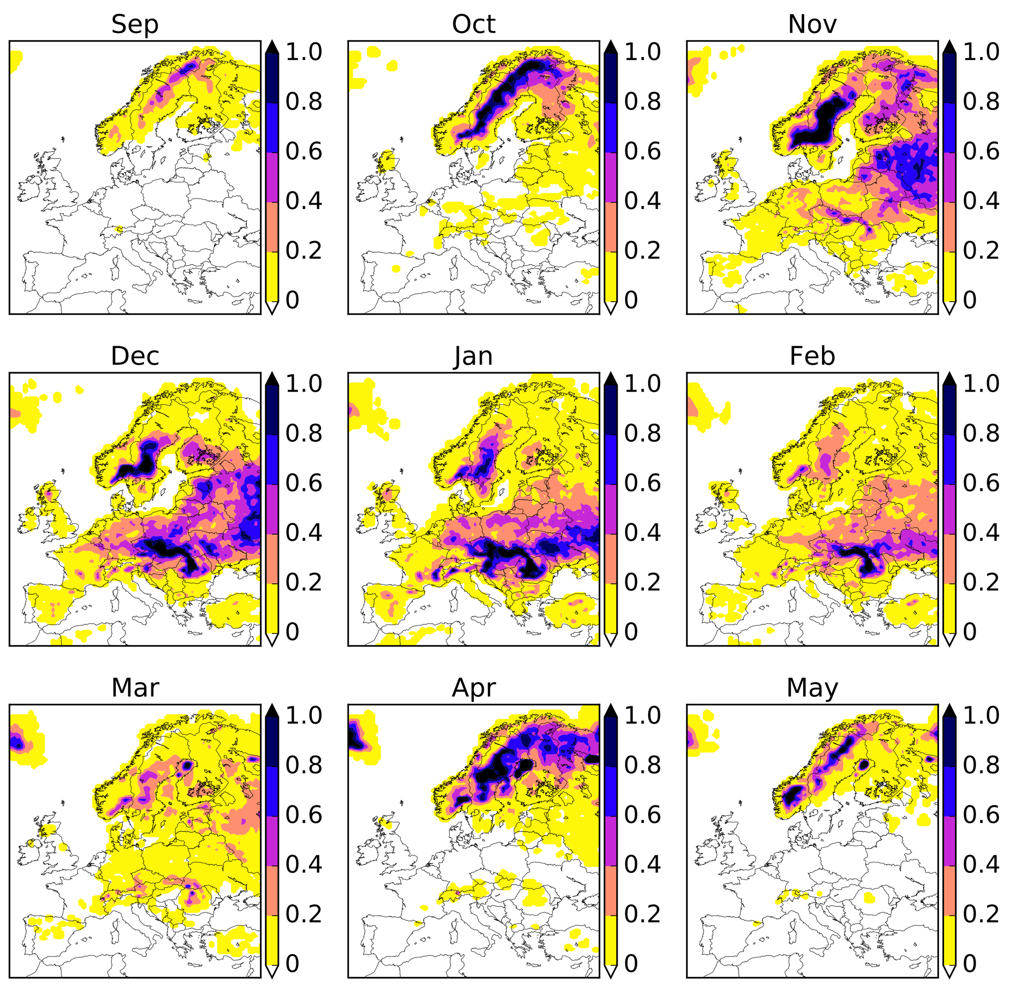

Figure 1: Mean monthly number of 6-hourly FZRA events in 1971-2000 according to the SMHI RCM, forced with the NorESM1-M global model.

Annual probability of severe FZRA events is highest in S-E Europe and especially over the Balkan Peninsula; there

- **P(5 mm/day/year)** = 5 – 50 %
- **P(25 mm/day/year)** = 0 – 5 %

3b Projected changes

- FZRA of **5 mm/day** is quite common in Europe, but **25 mm/day** is so rare that no events were found in most of the grid cells and therefore the direct calculation of changes was not possible.
- Changes in **5 mm/day** probabilities were dependent on the future period and emission scenario so that the strongest signals can be seen with RCP8.5 at the end of the century (Fig. 2).
- The current method confirms the earlier results attained with a coarser method (Kämäräinen et al. [2015]): FZRA is expected to increase in N-E Europe and decrease in central parts.

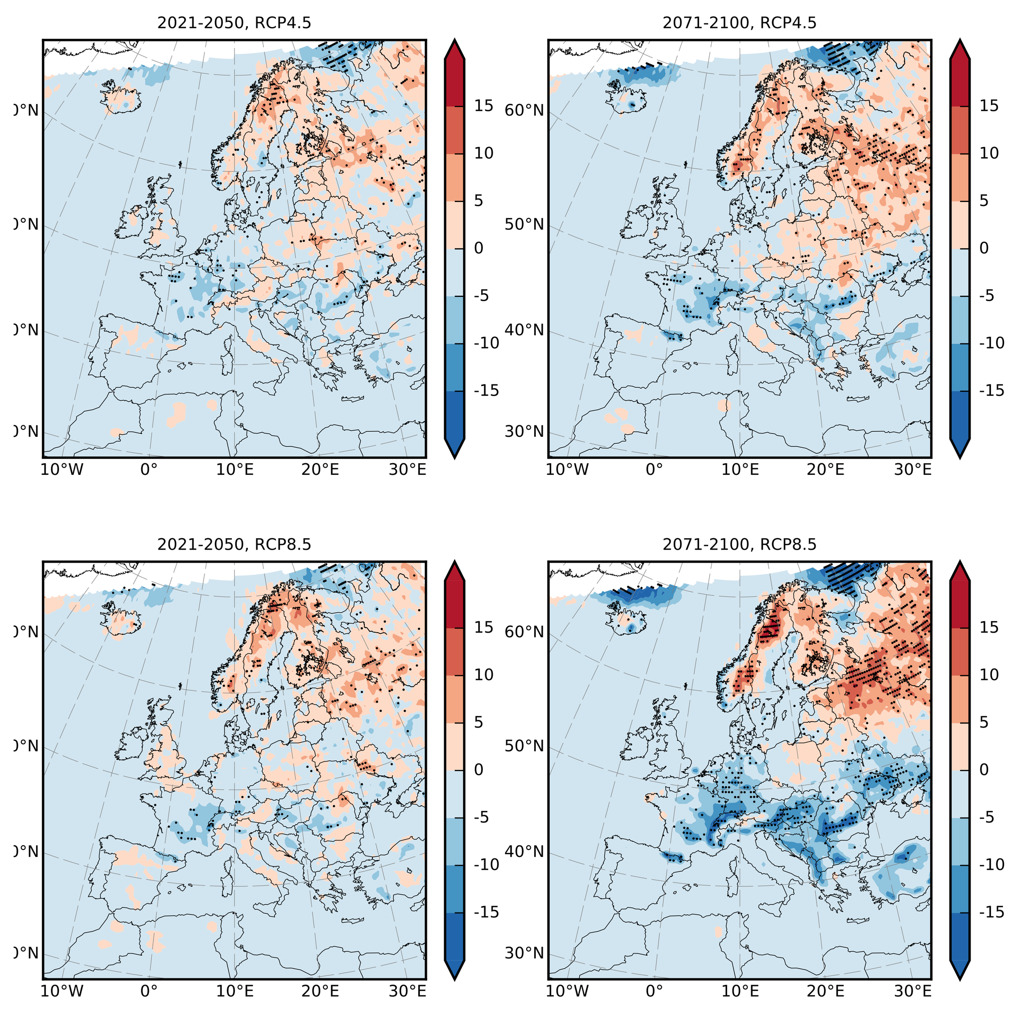

Figure 2: Projected multi-model mean changes in annual probability of at least one **5mm/day** FZRA event (percentage points). Statistical significance (P<5%) denoted with dots.

3c Analysis of T profile

To explain the climate changes seen in the results, a simplified analysis was performed for the T2m and T850. These variables together roughly describe the vertical temperature profile and the cold layer – melting layer structure. Figure 3 shows the 2-dimensional probability distributions for grid cells with positive or negative changes in occurrences of FZRA (red and blue areas in Fig. 2).

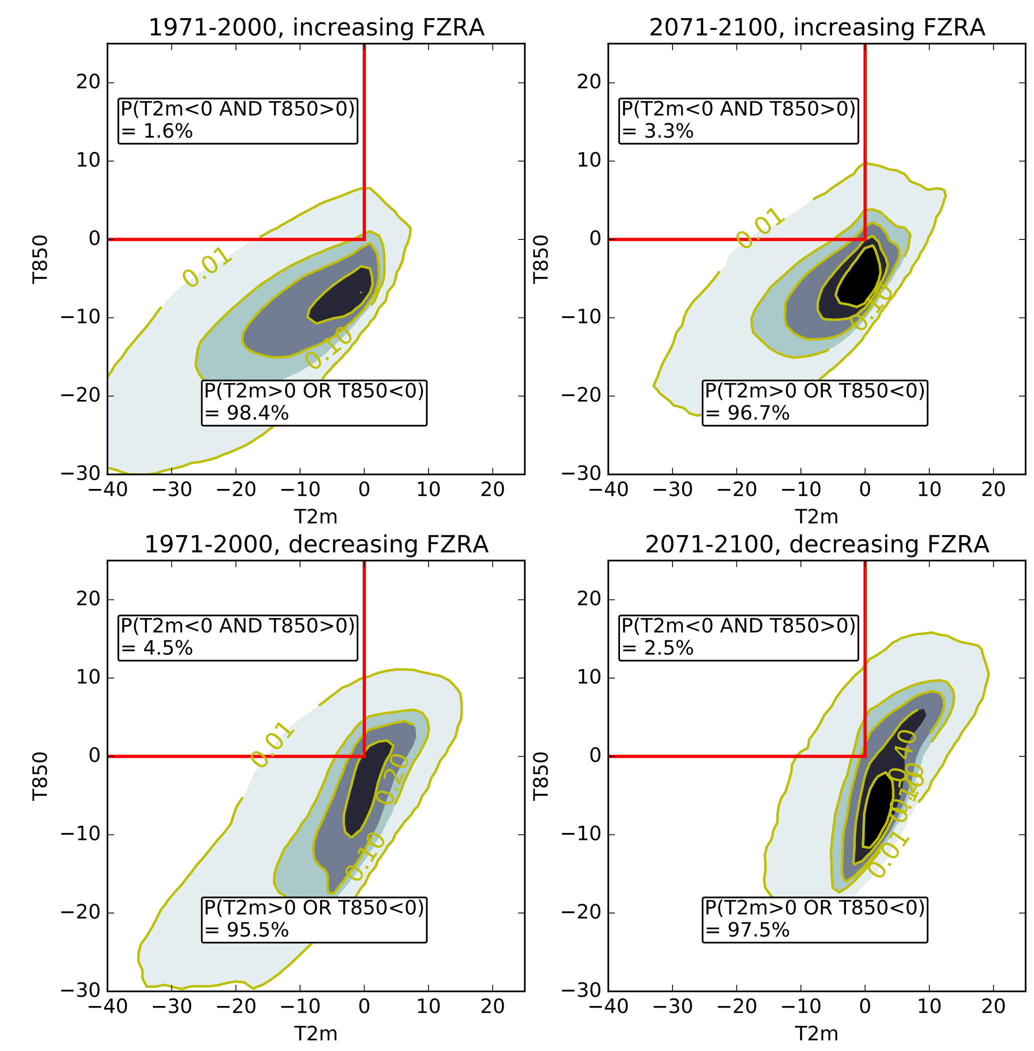

Figure 3: Kernel density estimates of near-surface temperatures (x-axis) and temperatures at 850 hPa level (y-axis) in Dec-Jan-Feb. Red rectangle indicates the area where FZRA is possible. Empirical probabilities are shown in boxes. Present-day and end-of-century periods are shown on left and right columns; N-E Europe and C Europe on top and bottom rows respectively.

Climate change shifts the 2-dimensional probability distribution of T2m vs. T850 differently in different parts of Europe: In N Europe the present-day winters are so cold that occurrence of a melting layer is very rare, but becomes more frequent in future. In C Europe the melting layer is common but the occurrence of the near-surface cold layer decreases towards future.

4 Conclusions

1. **RCM mean was able to capture the observed monthly climatological distribution of FZRA.**
2. **5 mm/day events are expected to increase in N and decrease in C Europe; 25 mm/day events are so rare that their changes are difficult to estimate at grid-cell scale.**
3. **Changes in vertical T profile explain the projected changes in FZRA occurrence.**
4. **Projected changes in the probability of FZRA events imply new challenges for risk management and climate change adaptation for critical infrastructure.**

References

M. Kämäräinen, K. Jylhä, A. Vajda, H. Gregow, P. Jokinen, and S. Saku. Identifying freezing rain events in European gridded climate datasets. *EMS Annual Meeting Abstracts*, 2015. URL `http://meetingorganizer.copernicus.org/EMS2015/EMS2015-32.pdf`.

M. Kämäräinen, O. Hyvärinen, K. Jylhä, A. Vajda, S. Neiglick, J. Nuottokari, and H. Gregow. A method to estimate freezing rain climatology from ERA-Interim reanalysis over Europe. *Nat. Hazards Earth Syst. Sci. Discuss.*, 2016. doi: 10.5194/nhess-2016-225.

A. Vajda, I. Juga, M. Kämäräinen, I. Lehtonen, and H. Gregow. Assessment of impact indicators for extreme winter phenomena considering critical infrastructure. *EMS Annual Meeting Abstracts*, 2015. URL `http://meetingorganizer.copernicus.org/EMS2015/EMS2015-388.pdf`.

Acknowledgements

This work has received funding from the **EU-FP7** project **RAIN** (grant number 608166) and from the Finnish Nuclear Power Plant Safety Research Programme 2015-2018 (**SAFIR EXWE**). We acknowledge RCM modelling groups from **SMHI**, **MPI-CSC**, and **KNMI** for providing the high-resolution data used in the project, and **TU Delft** for storing the project results (available at `https://data.4tu.nl/repository/collection:ab70dbf9-ac4f-40a7-9859-9552d38fdccd`).