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Identifying the freezing rain events
in European gridded climate datasets

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1 Summary
Wintertime freezing rain (**FZRA**) events are a hazardous phenomenon affecting the Central and Northern Europe. To gain detailed information about the present-day and future climatologies of FZRA, new methodology for identifying the events were developed, tested and applied to gridded climate datasets. Vertical profiles of T and RH in the ERA-Interim reanalysis and in CORDEX regional climate models were studied and SYNOP weather station observations were used as a reference. The number of freezing rain events is expected to decrease in Central Europe and increase in Eastern and Northern parts of the continent in future.

2 Data
• The present weather codes from manually operated 6-hourly SYNOP weather stations were used as a reference and for calibration of the methods (Fig. 1).
• 6-hourly ERA-Interim reanalysis data from different pressure layers was interpolated to station locations for development and calibration of the identification algorithms.
• Daily data in 50 km resolution from 12 regional climate models participating in the CORDEX modelling project was used for future assessments.
• The SYNOP observations and ERA-Interim data were also transformed to daily time resolution to be used in one part of the analysis.
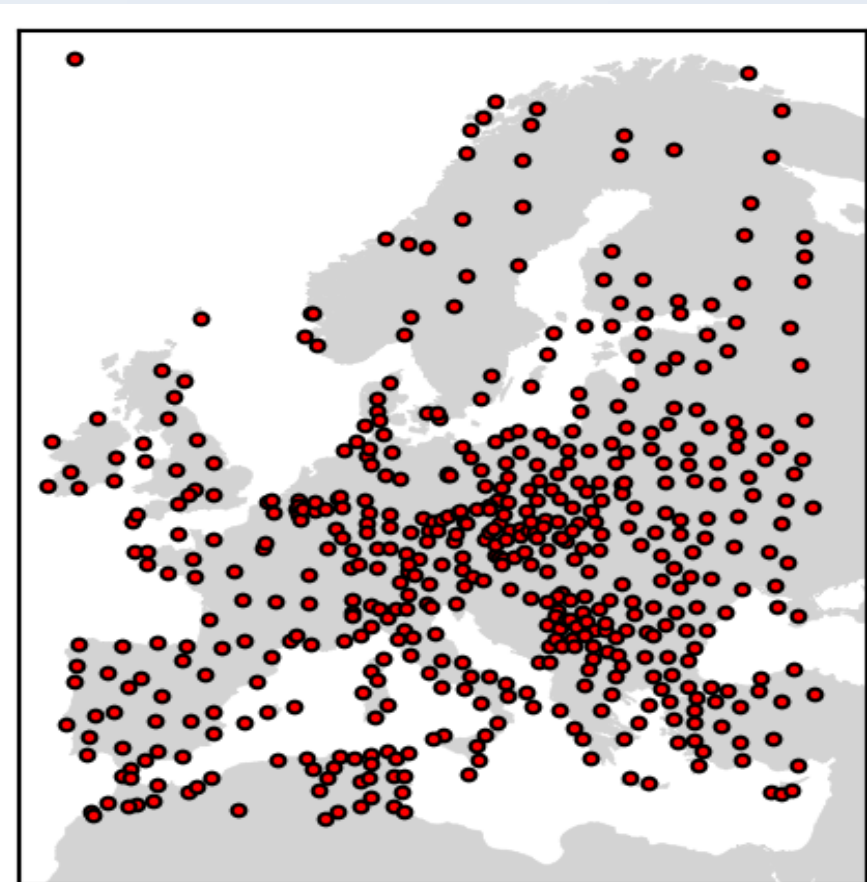

Fig. 1. *The 525 quality controlled SYNOP stations. If more than 80% of the 6-hourly present weather codes in 1981-2010 were available, the quality test was passed.*

3 Methods
• For present-day climatological analysis an operational precipitation typing algorithm of the Finnish Meteorological Institute was applied to 6-hourly ERA-Interim data (**FMI**).
• For freezing rain it uses T and RH information from 1000, 925, 850 and 700 hPa pressure levels and additionally searches the near-surface melting layer. (Fig. 2)
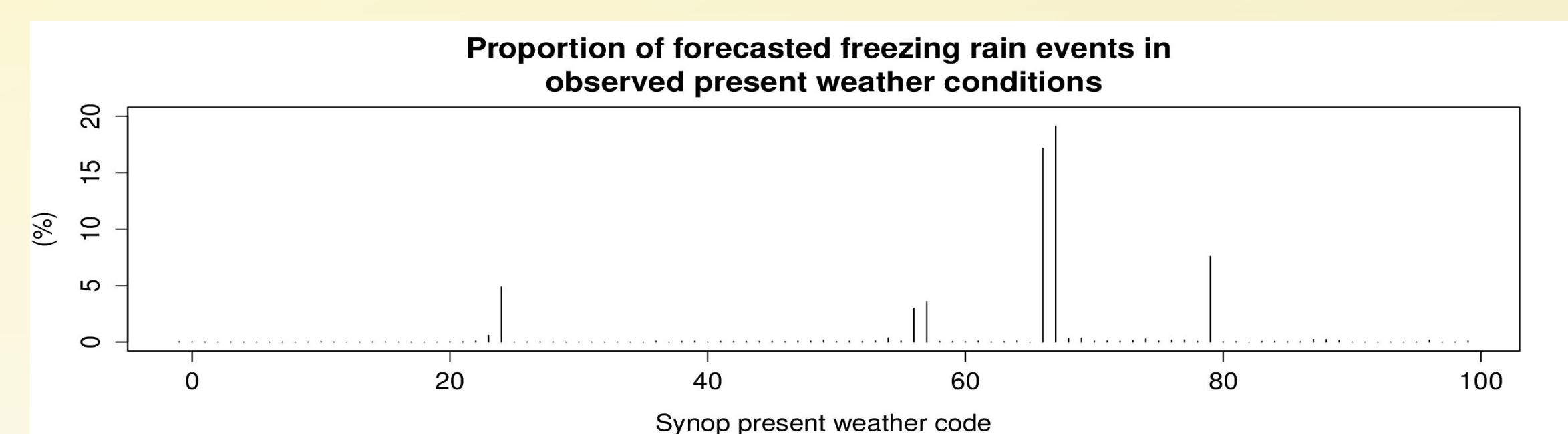

Fig. 2. *The forecasted freezing rain events (FMI algorithm) correspond mostly the observations in freezing rain SYNOP classes (24, 66, 67). Confusion to ice pellets (79) is relatively common.*

• For future climatology assessments, a new algorithm was developed (**NEW**).
• It uses T2m, Pr and T850 and operates also in time dimension trying to identify the warm weather fronts from the evolution of the T850 field.
• The ERA-Interim and SYNOP data were transformed to daily resolution and only stations below 600 m were used for the calibration of the NEW method.

4 Calibration of the NEW algorithm
• Numerical optimization of the Heidke Skill Score (**HSS**) metric with different threshold values (Fig. 3).
• Additionally a small mean bias (<5%) was required before application of the HSS test to avoid drifting towards overestimation of the number of the events.
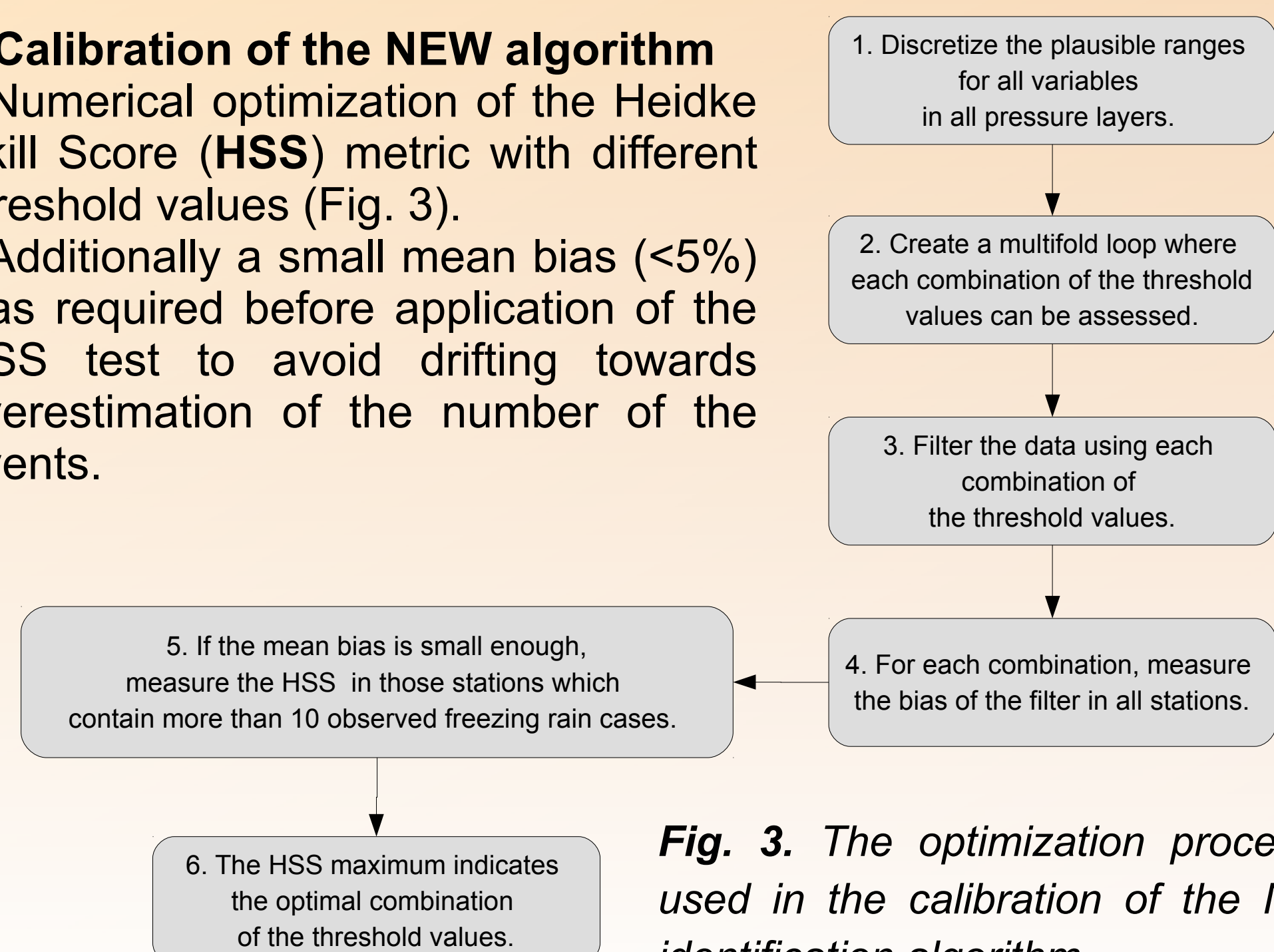

1. Discretize the plausible ranges for all variables in all pressure layers.

2. Create a multifold loop where each combination of the threshold values can be assessed.

3. Filter the data using each combination of the threshold values.

4. For each combination, measure the bias of the filter in all stations.

5. If the mean bias is small enough, measure the HSS in those stations which contain more than 10 observed freezing rain cases.

6. The HSS maximum indicates the optimal combination of the threshold values.

Fig. 3. *The optimization procedure used in the calibration of the NEW identification algorithm.*

5 Results
• The optimal threshold values for the NEW algorithm were the following:

$$FZR = (T\,850_{previous} < 7.20\,°C) \cap (T\,850_{current} > -1.62\,°C) \cap (T\,2\,m_{current} < 0.22\,°C) \cap (Pr_{current} > 2.01\,mm/day),$$

where the subscripts "previous" and "current" refer to previous and current days respectively. Freezing rain is identified if all the required conditions are true.
• Contrary to the NEW algorithm, the FMI algorithm is more suitable for the mountainous regions (Fig. 4).
• The results with the NEW algorithm applied to ERA-Interim show a relatively good agreement with station observations in low elevation areas (Fig. 4), but on average the climate models overestimate the occurrence of freezing rain in present-day climate (not shown). All the studied models show almost similar CC signal pattern (Fig. 5).
• The Heidke Skill Score value for the NEW algorithm was 0.20 and for the FMI algorithm 0.17.
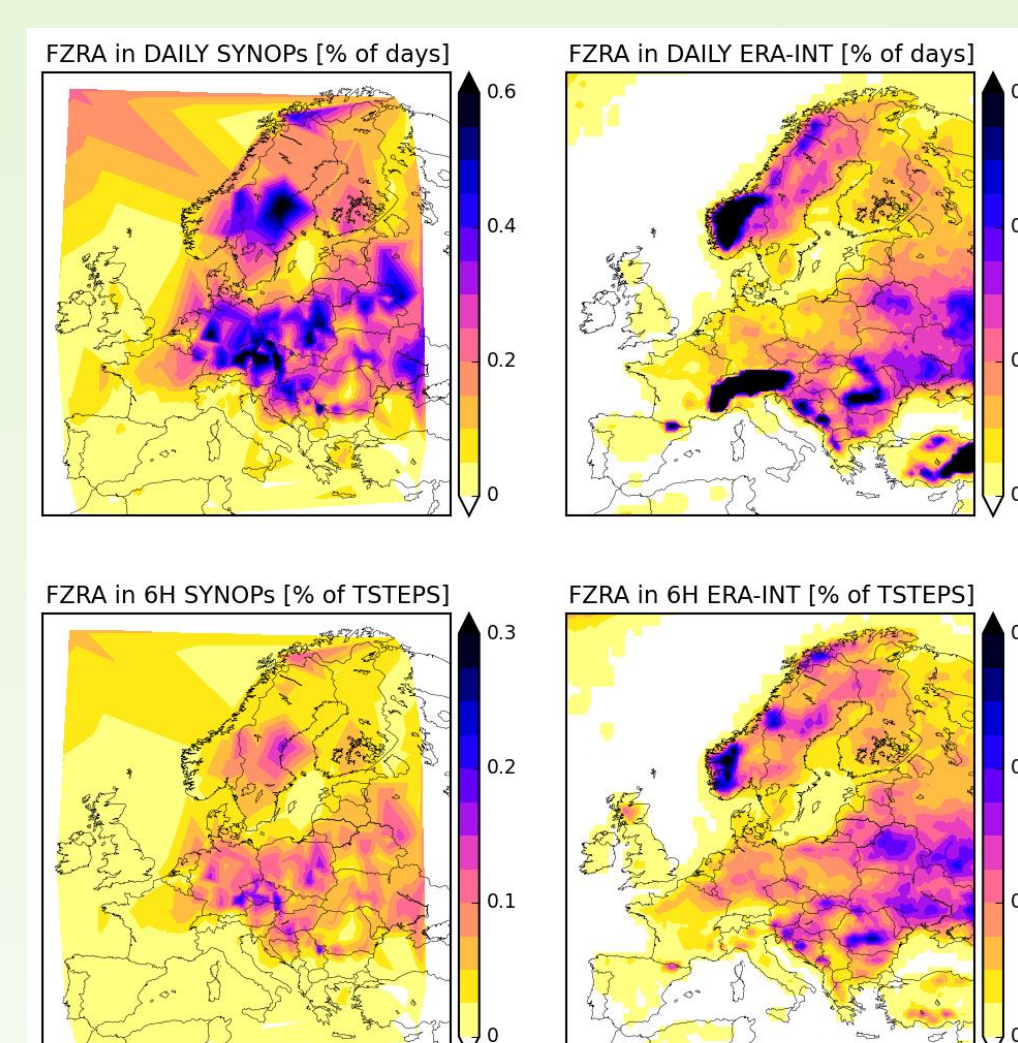

Fig. 4. *The 1979-2012 occurrence climatology of freezing rain in SYNOP observations (left column) and in the ERA-Interim reanalysis (right column) after application of the NEW (top row) and the FMI (bottom row) filters.*
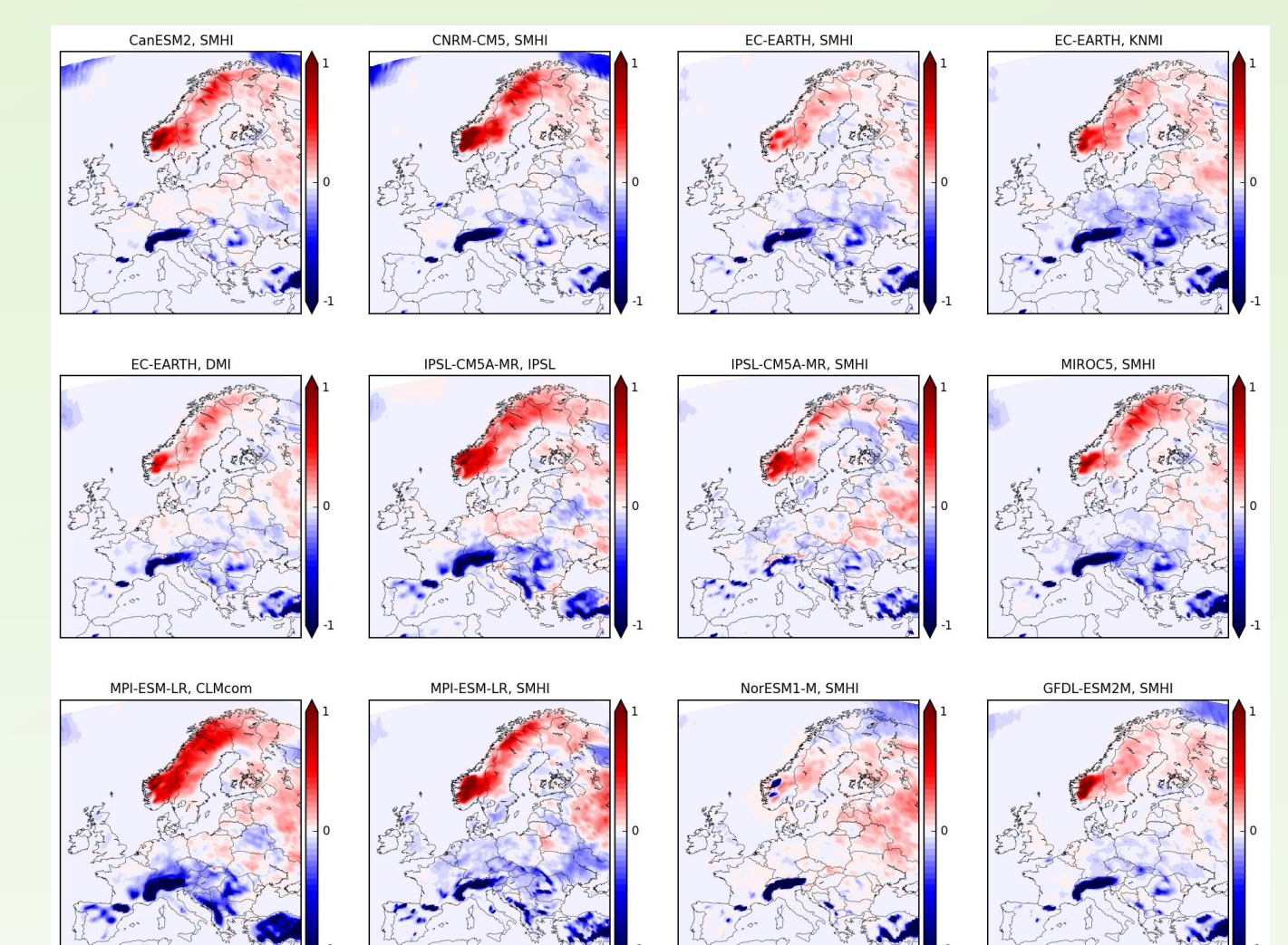

Fig. 5. *The estimated 1971-2010 → 2061-2095 climate change (in percentage points) of the occurrence climatology of freezing rain according to CORDEX RCP8.5 climate models filtered with the NEW algorithm. Mountainous areas (H > 1000 m) are likely to be incorrect.*

6 Conclusions and future steps
• Freezing rain could be identified in gridded datasets.
• Global warming shifts the area of FZRA occurrence northwards.
• Further work is still needed to improve the methodology (Fig. 6):
  • Additional quality control of the SYNOP data: removal of the suspicious cases.
  • Bias corrections of the climate data prior to the analysis.
  • Application of more sophisticated precipitation typing methods, eg. the Ramer algorithm.
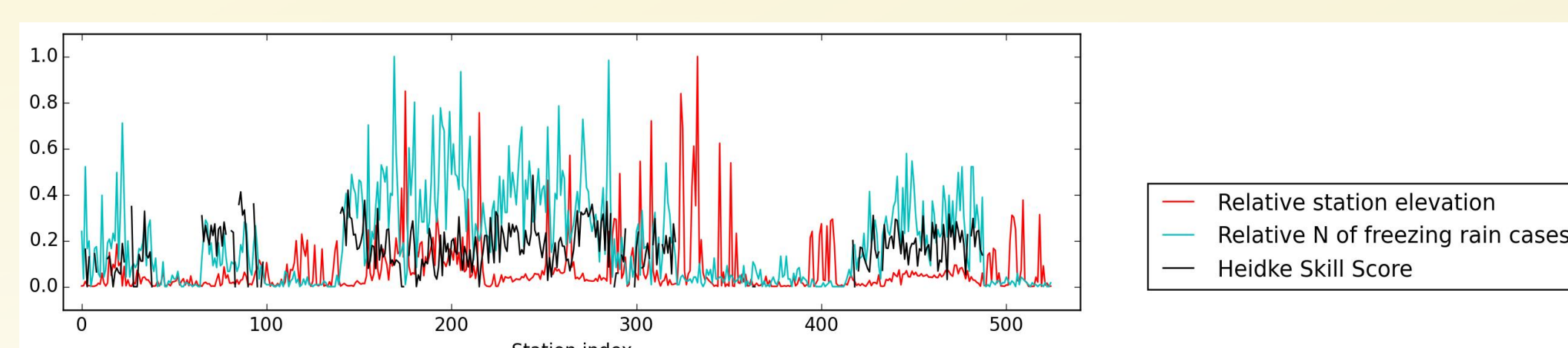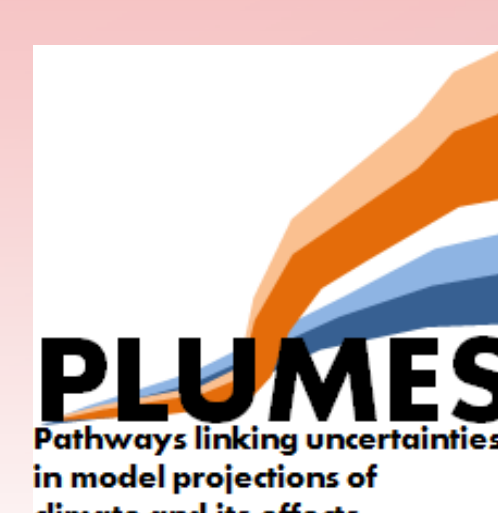 • Denser time and vertical resolutions for future simulations.

Relative station elevation
Relative N of freezing rain cases
Heidke Skill Score

Fig. 6. *The Heidke Skill Score of the FMI algorithm, the relative distance to the sea level, and the relative number of observed freezing rain cases in 1979-2012 for the 525 SYNOP stations. HSS is measured if a station contains more than 10 freezing rain observations.*