Convection in future winter storms over northern Europe.

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Introduction:

Precipitation within extratropical cyclones is very likely to increase towards the end of the century in an RCP85 scenario. This is the primary reason for wetter winters predicted for northern Europe (IPCC-WG1 2021, chap. 10).

In this study, we investigate how the nature of hourly precipitation and its rate may change in future winter storms with the first km-scale model ensemble covering northwest Europe and the Baltic region, which expicitly represent convection (Convection Permitting Models CPMs).

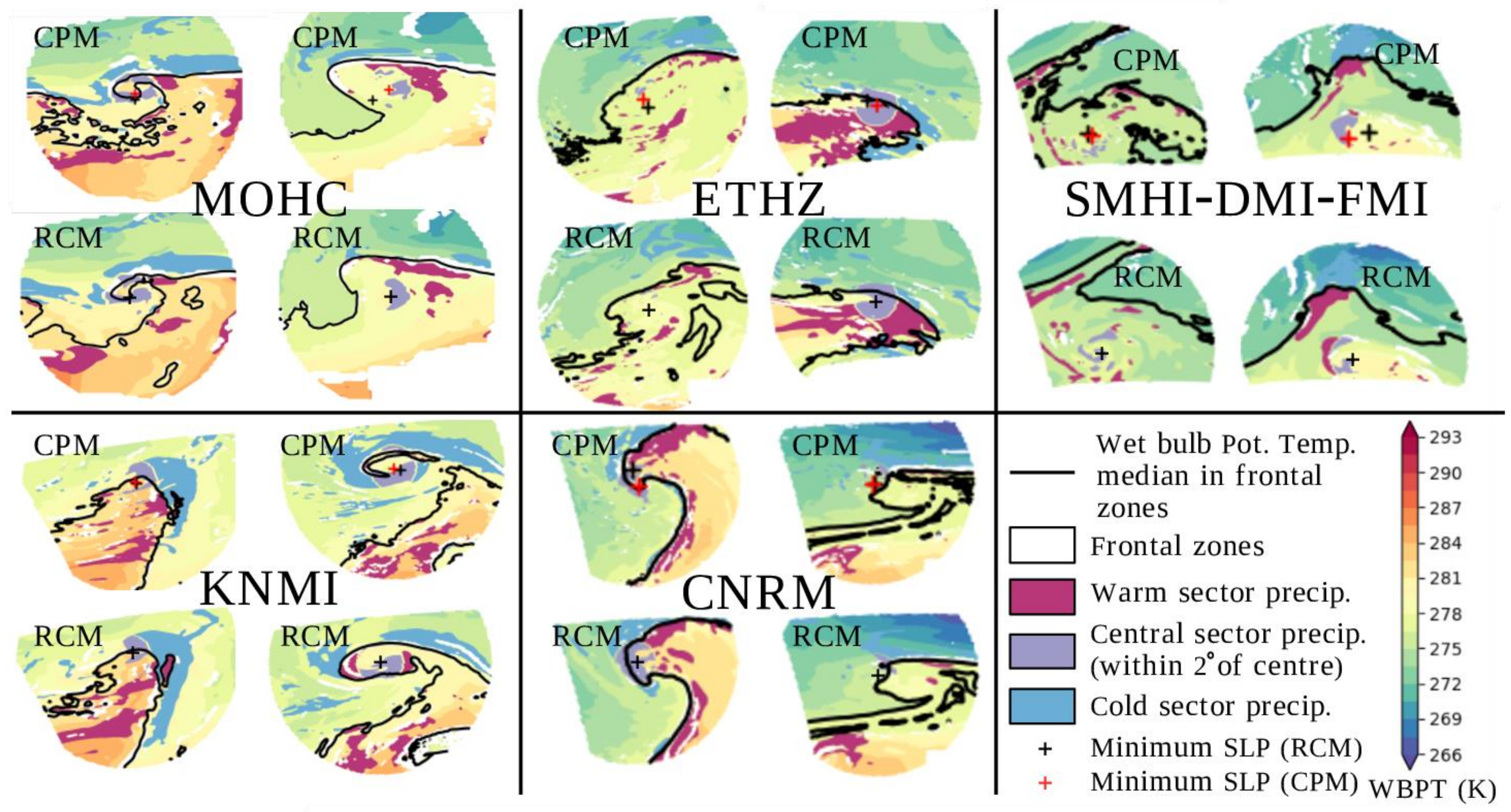


Fig1: This figure shows two sample storms per model pair. Precipitation is coloured by storm sector, defined using 850hPa Wet Bulb Potential Temperature gradients.

Method:

We looked at within-storm changes, to stay away from changes in number of storms, as the latter depends on the driving model.

Storm = extra-tropical cyclone tracked using sea level pressure with TempestExtremes

5 model pairs, each pair has:

- a 12km or 25km convection parameterised model (RCM)
- a 2-3km Convection-Permitting Model (CPM)

Present-day = 10 years around year 2000

Future = 10 years towards the end of the century in an RCP8.5 scenario.

Each winter storm is likely to bring 10 to 50% more precipitation, due to similar occurrences of weak precipitation but increased moderate and intense precipitation, mostly located in the warm sector.

Comparing areas under these curves gives the % increase in mean precipitation per storm, 32% in this case.

Increase comes from moderate to heavy precipitation rates, no decrease in weak precipitation.

The warm sector is the largest contributor to precipitation increases, and most CPMs show larger increases in the warm sector for heavy precipitation rates (compare plain to dashed red line)

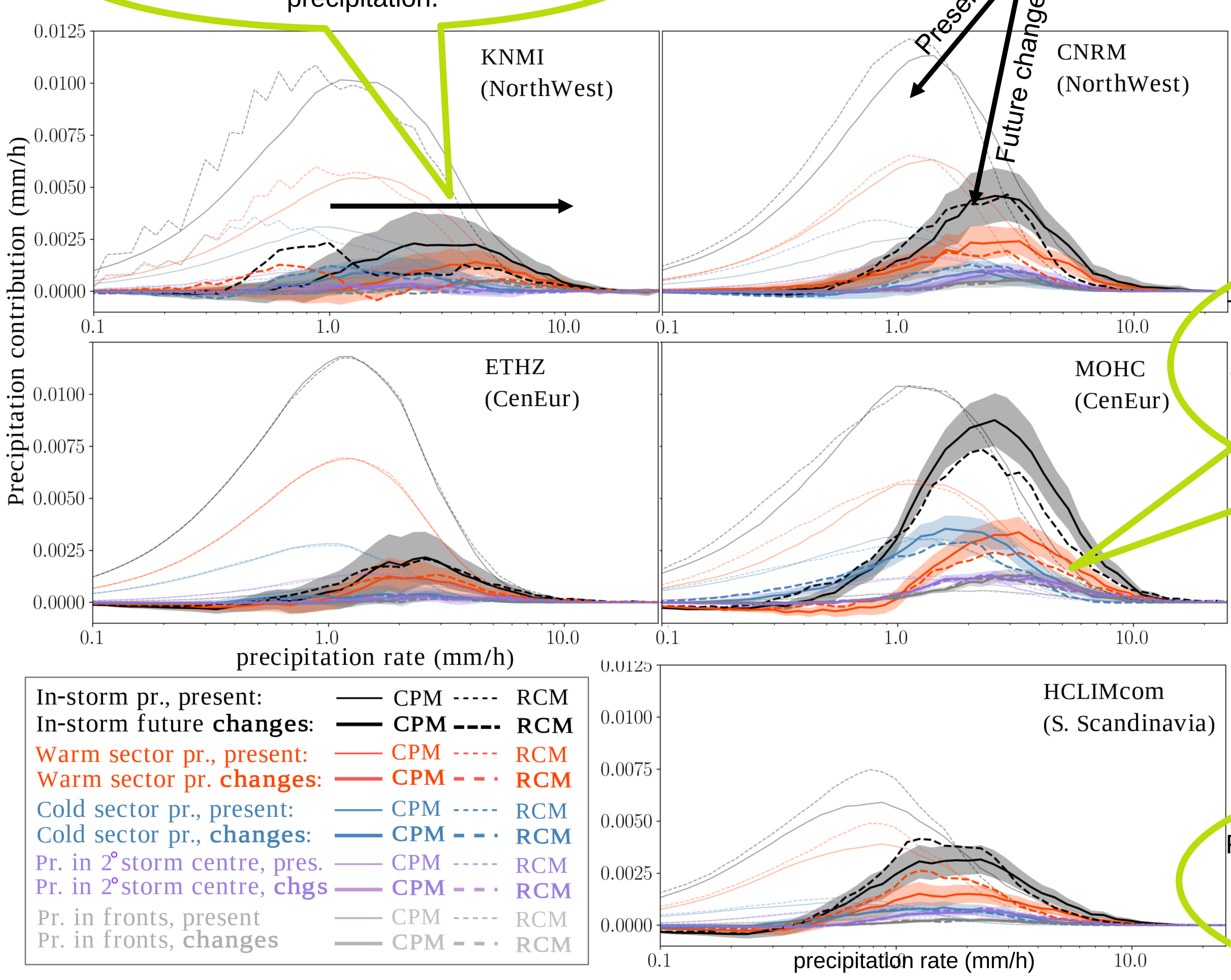
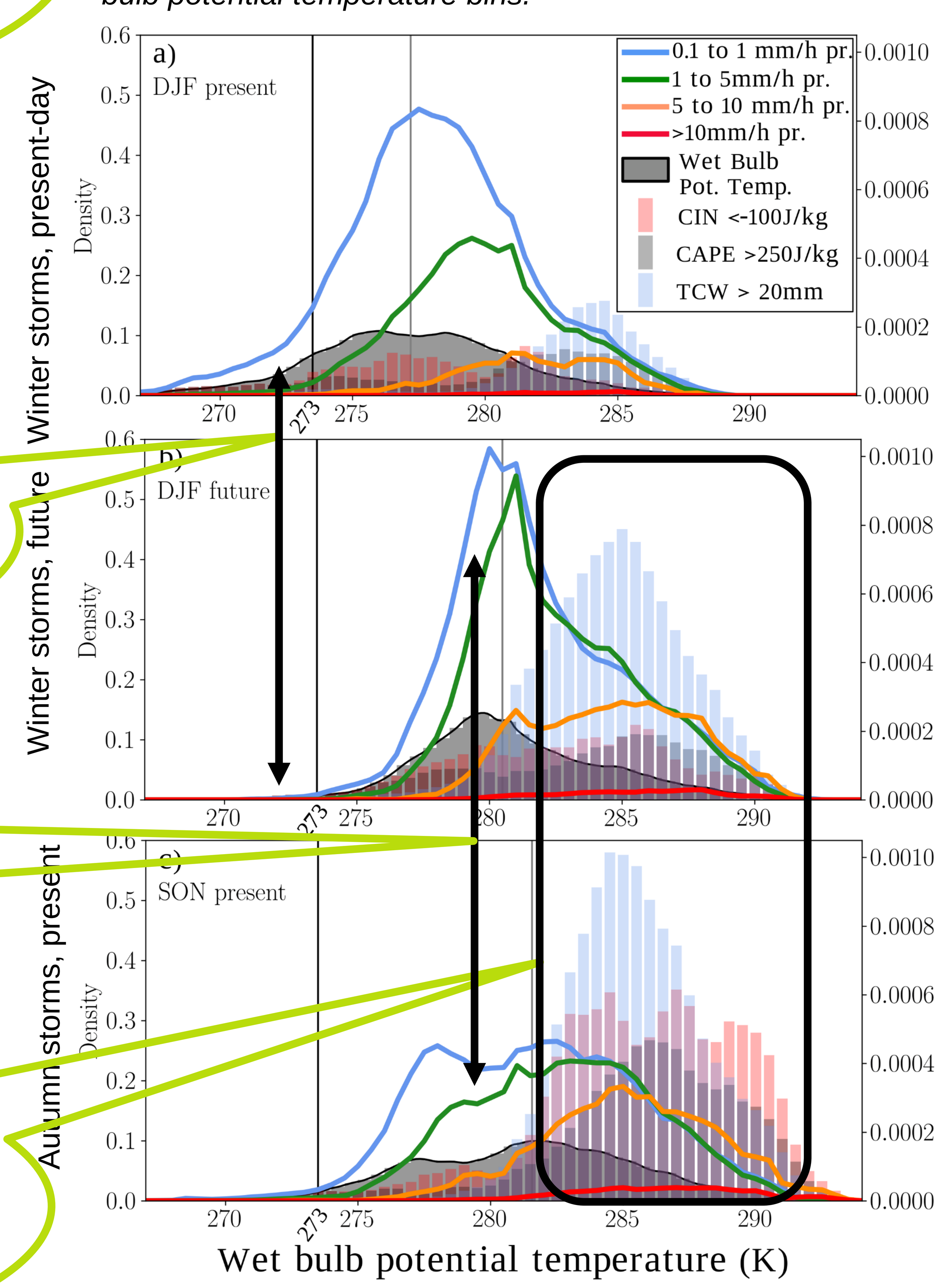


***Fig. 2:** Winter precipitation contribution to the mean within storms (frequency x value of bin, using exponential bins defined in Berthou et al. (2019) for each model pair. Thick lines: precipitation changes, thin lines: present-day distribution. Colours correspond to definition of storm sectors in Fig. 1.*

Additional conclusions (not illustrated here):

Differences between models are linked with differences in their warming levels in the warm sector of storms and differences in changes in dynamical strength of storms. The latter is less certain, with little model agreement (in line with Catto et al. (2019), also potentially because dynamical strength is more prone to inter-decadal variability (only 10-year time slices in this study).

***Fig. 3:** This is a storm composite for the MOHC CPM (model with greatest warming), obtained by binning frequency of variables above or below a threshold by wet bulb potential temperature bins.*



Frequency of frozen precipitation within winter storms will very likely decrease, as wet bulb potential temperature may hardly reach 0°C.

Light and moderate precipitation frequency in future winter storms remain higher than in today's autumn storms, likely because relative humidity remains higher in winter than autumn (not shown here).

In the model with the greatest warming, future winter storms have similar warm sector precipitation rates as current autumn storms, along with higher values of Convective Available Potential Energy (CAPE), Convective Inhibition (CIN) and Total Column Water vapour (TCW).

Conclusions for the km-scale modelling community:

This study shows that the larger increase in mean precipitation in winter storms in the MOHC CPM is not found in other RCM/CPM pairs. **We therefore recommend to look at multi-model ensembles when possible.**

We showed that CPMs are useful tools to better understand changes in intense rain rates and fine-scale processes in winter storms. Nevertheless, levels of warming within the warm sector of storms and dynamical strength of storms, well captured by RCMS, are the largest factors explaining mean and intense precipitation changes in storms.

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