Response to referee #2

The manuscript provides an assessment of whether a high-resolution (2.2 km) regional climate model (COSMO-crCLM) can represent the "reverse orographic effect" - an observed effect whereby short-duration (e.g., hourly) extremes in precipitation decrease with increasing altitude. The study is performed over northeastern Italy including some of the Italian Alps - a region of complex orography. The authors make use of a statistical technique: simplified metastatistical extreme value (SMEV) to reliably determine return times longer than the duration of their simulations (10 yr). They find that the model does produce a reverse orographic effect, albeit with reduced magnitude compared to rain gauge observations.

The manuscript is well written, with clear figures and a logical structure. The interpretation is all backed up by the figures. Uncertainties are assessed using a boostrapping method (random sampling of years with replacement). Potential sources of bias, from underestimation of the rain gauges to differences in the elevations of the gauges and the co-located grid cells, are considered. The discussion further considers why the model might be underestimating the effect, discussing the effective resolution of the model as well as the representation of subgrid processes such as turbulence. All of the points that arose as I was reading the manuscript were addressed in the discussion.

I have therefore recommended publication with technical changes only. Below are some very minor comments and clarifications.

Authors' response: We thank the reviewer for the positive feedback and the provided comments/corrections. We address them in the following. We numbered each comment as R2Cx (Referee 2, Comment x), and our response is indicated with "R" and blue color. In the proposed modifications to the original text, we indicate the new text in *Italics*.

R2C1. General:

- divide symbol (÷) seems to be used where a dash should be used.
- slice/s - I would normally prefer the word period/s
- Fig. vs Figure, consistency.
- I believe collocate should be colocate or co-locate.

R: The suggested corrections will be included in the revised paper.

Specific:

R2C2. Title: suggest changing to "How well does a convection-permitting regional climate model represent the reverse orographic effect of extreme hourly precipitation?"

R: We agree with your suggestion and we will include "regional" in the title.

R2C3. L14: Recent observational studies…

R: We will modify it according to your suggestion.

R2C4. L21: northeastern (no capital)

R: We will modify it according to your suggestion.

R2C5. L45: become -> are becoming

R: We will modify it according to your suggestion.

R2C6. L45: CMPs -> CPMs

R: We will correct the mistake.

R2C7. L77: spell out what the "reverse orographic effect" is: i.e. short-duration extremes decrease with increasing altitude (or similar).

R: We will rephrase adding an explanation of the "reverse orographic effect". It could be something like this: "While the orographic enhancement is also observed for relatively long-duration precipitation extremes (few hours or more), the opposite has been reported for short-duration extremes (hourly and sub-hourly), the so-called "reverse orographic effect" (Avanzi et al., 2015). *This is known as the "reverse orographic effect", i.e. the rainfall intensity decreases with increasing elevation (Avanzi et al., 2015)."*

R2C8. L152: GPU -> GPUs

R: We will modify it according to your suggestion.

R2C9. L153: More details on the physical parameterisations...

R: We will add the following description: "*The model solves numerically the fully compressible governing equations using finite difference methods (Steppeler et al., 2003) on a three-dimensional Arakawa-C grid (Arakawa and Lamb 1977) based on rotated geographical coordinates and a generalized, terrain following height coordinate (Doms and Baldauf 2015). A fifth-order upwind scheme is used for horizontal advection and an implicit Crank-Nicholson scheme in the vertical discretized in 60 stretched model levels ranging from 20 m to 23.5 km (Baldauf et al., 2011). The model employs a third-order Runge-Kutta time-stepping scheme (Wicker and Skamarock, 2002) and a delta-two-stream radiative transfer scheme according to Ritter and Geleyn (1992).The parameterization of precipitation is based on a single-moment bulk cloud microphysics scheme using five categories of hydrometeors, i.e. cloud water, cloud ice, rain, snow, and graupel (Reinhardt and Seifert, 2006). A modified version of the Tiedtke mass flux scheme with moisture convergence closure (Tiedtke, 1989) is used to parameterised shallow convection, while deep convection is resolved explicitly. In the planetary boundary layer and for the surface transfer a turbulent kinetic energy-based parameterization is applied (Mellor and Yamada, 1982; Raschendorfer, 2001) , while in the lower boundary COSMO-crCLIM uses the soil-vegetation-atmosphere-transfer model TERRA-ML with 10-layer soil and a maximum soil depth of 15.24 m (Heise et al., 2006)."*

R2C10. L153-4: Also, it would not hurt to describe some of the key parametrizations here, such as the microphysics (1-moment or 2), and the turbulence parameterization, so that the reader does not have to dig into the references. 2-3 sentences perhaps on these.

R: Please, see the answer above to the previous comment.

R2C11. Fig. 1b: Cannot see OB at low elevations. Perhaps plot as blue line (staircase - i.e. with flat tops/vertical lines) on top of SC_CPM?

R: At low elevation OB and SC_CPM histograms overlap, and the color of the bars is different where they are overlapping (a darker orange). We tried to use a staircase plot, as suggested, but it seems less clear than the histogram. We prefer to keep the histogram, and we will use larger bins (classes of 200 m, as shown below).
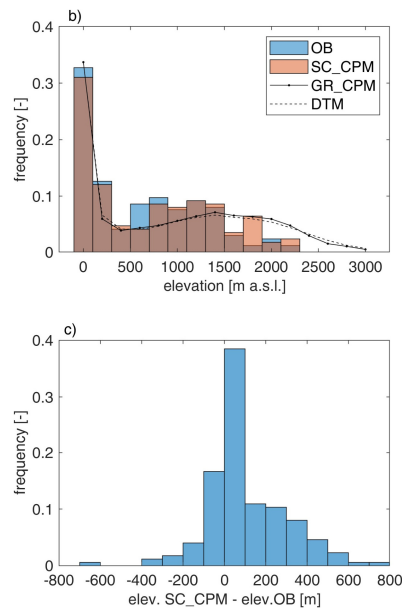
R2C12. L218: left-censoring - what does this mean?

R: We will rephrase to: "parameters of the Weibull distribution are calculated by left-censoring the ordinary events below the above-mentioned thresholds *(i.e., censoring their magnitude but retaining their weight in probability)* and using a least-squares linear regression in Weibull transformed coordinates".

R2C13. L244: AM defined as Annual Maxima, i.e. already plural. This means AMs should probably not be used later. (Very pedantic.)

R: We will correct AMs in AM, as suggested.

R2C14. L274: 30% km-1 - please remind reader of the definition without having to refer back to Sect. 3.3.

R: We will add here the definition: "30% km-1 *(expressed as percentage of the median value per km of elevation)* …"

R2C15. L275: Add details of regression R^2/fmse?

R: We will add the value of R^2 in all the figures showing regression lines (see as example the modified Figure 4).
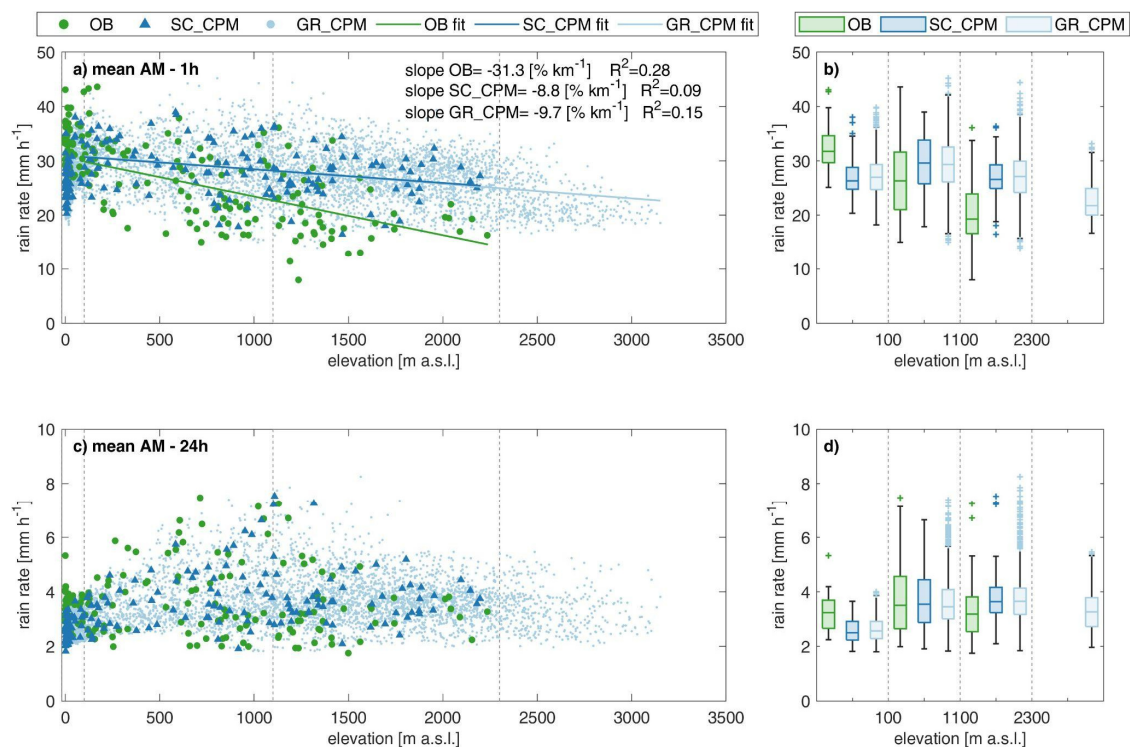
R2C16. Fig. 2b: suggest adding a vertical dashed line at elevation = 100 m, or showing all points below this as open circles, to visually show they are not included in the regression.

R: Thanks for the suggestion, we will add a vertical dashed line at elevation = 100 m a.s.l. (see modified figure below), and we will update the caption: "[...] slope for the linear regression *(solid line)* is expressed as a percent of the median value and is calculated for the stations above 100 m a.s.l. *(points on the right of the dashed line)*."
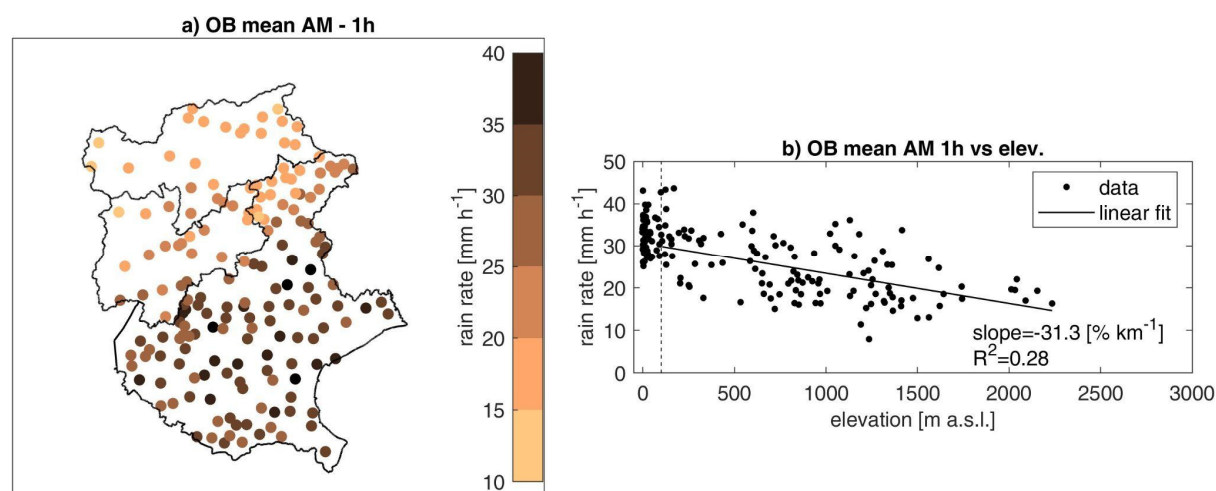
R2C17. L284: Figure 3a, b) instead of c)?

R: Yes, thank you for the correction.

R2C18. L286: (b) and (d)

R: Yes, thank you for the correction.

R2C19. L305: missing full stop.

R: Thank you for the correction.

R2C20. Figs. 4, 6: should have a blue triangle in key for SC_CPM (looks green on zooming in to PDF for me)

R: Thank you for this correction, we will update the legend for the SC_CPM with the correct color (blue), in Figure 4 and also Figures 6, S3, S4, S5

R2C21. L348: "The slopes test significantly different at the 5% level." Clarify - slopes of what are different to what?

R: We will modify it as: "The SC_CPM slope is significantly different (5% significance level) from the OB slope".

R2C22. L355: Figure S3 reports the uncertainty in the observed 1 h duration...

R: We will add "observed" as suggested.

L362: ...uncertainty indicate that...

R2C23. R: We will add "indicate" as suggested.

R2C24. L382: it seems to me as if GR_CPM shows less dependence on return period than SC_CPM is worth saying something about. Perhaps one sentence saying this?

R: Thank you for your comment. We will add a sentence about this: "The slopes obtained from the analysis on the whole CPM grid *show a milder decrease for higher return time than the SC_CPM slopes, but since they* are within the uncertainty range of the SC_CPM slopes, *no statistically significant result can be inferred on this.*

R2C25. L392: ...found in a CPM.

R: We will add "a" as suggested.

R2C26. L396: , with the lower values of the interquartile ranges...

R: We will add "lower" as suggested.

R2C27. L398: ...would be double that of the observations...

R: We will correct it.

R2C28. Sect. 5.3: suggest renaming this to "Bias assessment of differences in CPM and rain gauge elevations" (as a short subsection), and moving 5.3 to just before L430.

R: Thank you for the suggestion, but we prefer to keep it as it is, avoiding having an additional very short section.

R2C29. L433: undercath (typo)

R: We will correct: "undercatch".

R2C30. L472: ...estimation of hourly return levels...

R: We will add "hourly" as suggested.

R2C31. L487: ...in the case of strong wind.

R: We will add "the" as suggested.