Response to Anonymous Referee #1

The manuscript "REDCAPP (v1.0): Parameterizing valley inversions in air temperature data downscaled from re-analyses" by Cao et al. presents a new technique to downscale temperature data in mountainous regions whereby they develop a land-surface correction factor. They then demonstrate this technique for two mountainous regions: the Swiss Alps and Qilian Mountains. The technique that the authors develop is of interest to GMD readership, but the following comments need to be addressed before the manuscript is considered for publication.

The authors would like to thank the reviewer for the constructive feedback, and the thorough assessment of the manuscript. Below we provide a point-to-point response to each comment, reviewer comments are given in black, responses are given in blue. Additionally, we have included details of how we intend to address these changes in a revised submission.

General comments:

I am missing a discussion of how the method that the authors developed in the present manuscript differs from other downscaling approaches that already exist for complex or mountainous terrain. There needs to be more discussion of how the authors' method improves upon and is better than pre-existing downscaling techniques that also use variable lapse rates and incorporate information about the land surface and topographical characteristics, e.g. the Parameter-elevation Regression on Independent Slopes Model (PRISM) (Daly et al., 2000; Daly et al., 2002), the Daily Surface Weather and Climatological Summary (DAYMET) (e.g., Thornton et al., 1997), and the techniques used in Hijmans et al. (2005).

We will add a detailed discussion (see below) of comparisons of REDCAPP and existing methods (e.g. PRISM, DAYMET and other approaches) as a new Section 6.1 "Comparison with other downscaling techniques".

6.1 Comparison with other downscaling techniques

Many existing downscaling approaches for mountainous terrain focus on deriving fine-scale T through interpolation (e.g. truncated Gaussian weighting filter, Inverse Distance Weighting, or Kriging) of surrounding observations, and adjustments are then made based on fine-scale topography. PRISM (Parameter-elevation Regressions on Independent Slopes Model) (Daly et al. 2000; Daly et al. 2002), for example, derives a weighing function to represent the relationship of T with geographic (e.g. slopes, coastal) and meteorological (e.g. atmosphere boundary-layer) factors. Similarly, the approach by Thornton et al. (1997) calculates interpolation weights for the stations nearby, and corrected the downscaled results based on an empirical relationship of T to elevation, and Hijmans et al. (2005) conducted a second-order spline interpolation using latitude, longitude and elevation as independent variables. As observations are usually sparse in mountains, especially at higher elevation, these methods are expected to often have significant uncertainty caused by inadequately sampling of elevation and hence lapse rate. In comparison, REDCAPP relies on reanalysis data for air temperature and uses station data only for calibration of the LSCF related to CAP. REDCAPP derives lapse rates from multiple layers of upper air temperature *encompassing the entire elevation range of study area. Thus, REDCAPP results are expected to be robust because both the Tsa and Tpl from reanalysis are used.*

The temperature lapse rate is defined as decreasing with height and thus a negative lapse rate implies a temperature increase with height. This change needs to be implemented throughout the manuscript.

Thank you for pointing this out. We corrected throughout the manuscript, changes are listed below:

(1) *"For example, Lewkowicz and Bonnaventure (2011) reported that average lapse rates could be positive in mountains due to strong winter inversion and result in lower T in valleys than at higher locations."* is changed to

For example, Lewkowicz and Bonnaventure (2011) reported that T in valleys was lower than at higher locations in mountains due to strong winter inversion.

(2) *"This is because the lapse rates are expected to decrease owing to the presence of CAPs."* is changed to

"This is because the lapse rates are expected to ***increase*** *owing to the presence of CAPs."*

In Section 3.2, more discussion is required about the meteorological stations that the authors used, e.g., instrument type, completeness of the data sets at these stations within the two study regions, etc. Also, the authors mention in line 3 of page 5 that mean daily temperatures in 1980 or after are used. The total time period of the study needs to be indicated. I am also not sure what the authors mean by "obviously wrong values" on pages 4-5 in this section. More description is necessary here too.

Yes, we agree the discussion of observations will benefit from more detail. We reformulated this part by adding the instrument type and accuracy. Additionally, a figure showing observation completeness is added in Figure 2.

The *"obviously wrong values"* means the value out of the range of -60 to 60 °C or not consistent by comparing values with the day before and after the checking day.

"The temperature from MeteoSwiss is observed using the Thygan instrument which has an accuracy of ± 0.01 °C, and temperatures from IMIS are measured by several different sensors (including Rotronic MP100H, Rotronic MP102H/HC2, Rotronic MP103A, Campbell Scientific CS215), with sensor accuracies ranging from ± 0.1 to ± 0.9 °C. In the Qilian Mountains, temperature sensor HMP155 with a typical accuracy of ± 0.2 °C are used. The 395 stations used cover an elevation range of ~250–4150 m as well as different topographic positions including peaks, slopes, plains and deep valleys (Figure 2a).

All temperature observations were filtered using a threshold (plausible values from -60 to 60 °C), and the outliers of temperature time series were removed by visually check. Time offsets between observations and ERA-Interim are avoided by conducting all analyses in UTC time. When using mean daily temperature, days with missing data were removed before further analysis. Though there are totally 395 stations used here, not all of them are available in a single year (Figure 2b). In total, there are ~2.5 × 10^6 observations of mean daily temperature in or after 1980 used here."

In Section 5.3.1, the authors note that the bias in the Swiss Alps increases with the implementation of the REDCAPP technique, but no explanation is offered as to why this is.

To clarify, we added

"This is because REF3 resulted in air temperatures being too low at high elevation, while the influence of CAP was underestimated in valleys by applying a fixed LSCF of 1 to the entire area. As a result, the BIAS of REF3 is very close to 0 due differing biases cancelling out each other."

The quality of many of the figures needs to be improved. Figure 1 would benefit from a zoomed out map showing the relative locations of the study areas in the Swiss Alps and Qilian Mountains. In Figures 4, 10, and 11, are these means or medians shown with the red dots? Please include this information in the legends for these respective figures. In Figure 5 and in Figure 11, what time period is being shown for each of the stations? This information should to be included either in a separate table or in the figure captions. Finally, the latitude and longitude should be included directly on Figure 8, Figure 13, and Figure 2, rather than in the caption, in order to improve the figures' readability.

Please note that the number of plots are changed. The number used below are new ones.

Figure 1: A figure with the relative locations of the Swiss Alps and Qilian Mountains is added.

Figure 2: The elevation distribution from previous Figure 1 and a new plot of station used in different years are set as Figure 2.

Figure 5, 11 and 12: the red dots are median values, and this information will be added in the respective captions in a revised submission.

Figure 6 and 13: the observation periods are provided in Table 3.

Figure 9, 13 and A2: latitude and longitude are added.

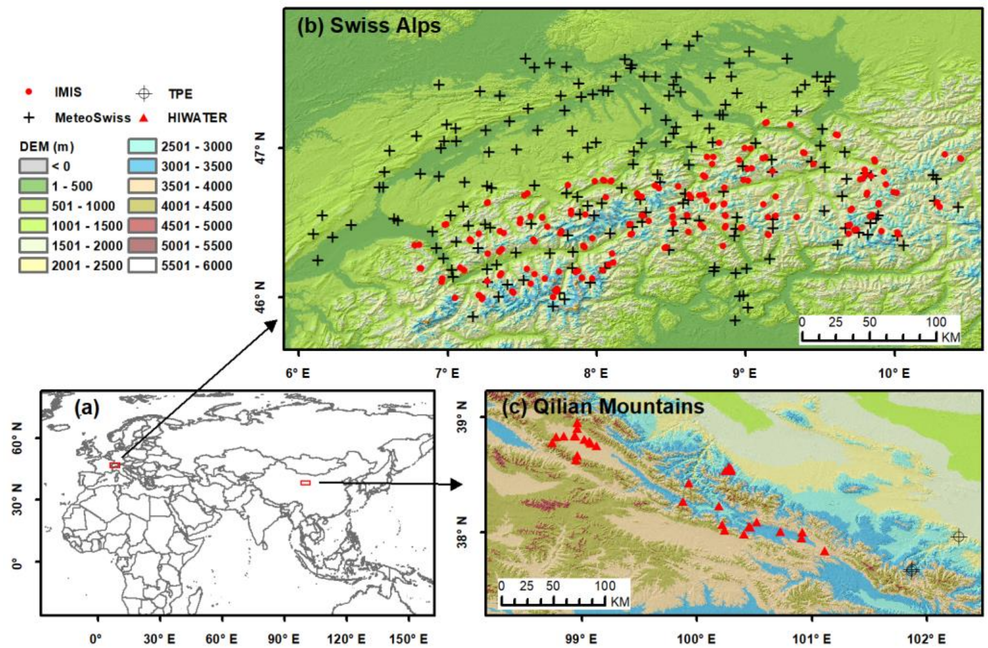

Figure 1 Location of experimental region (a), observation stations in the Swiss Alps (b) and the Qilian Mountains (c).

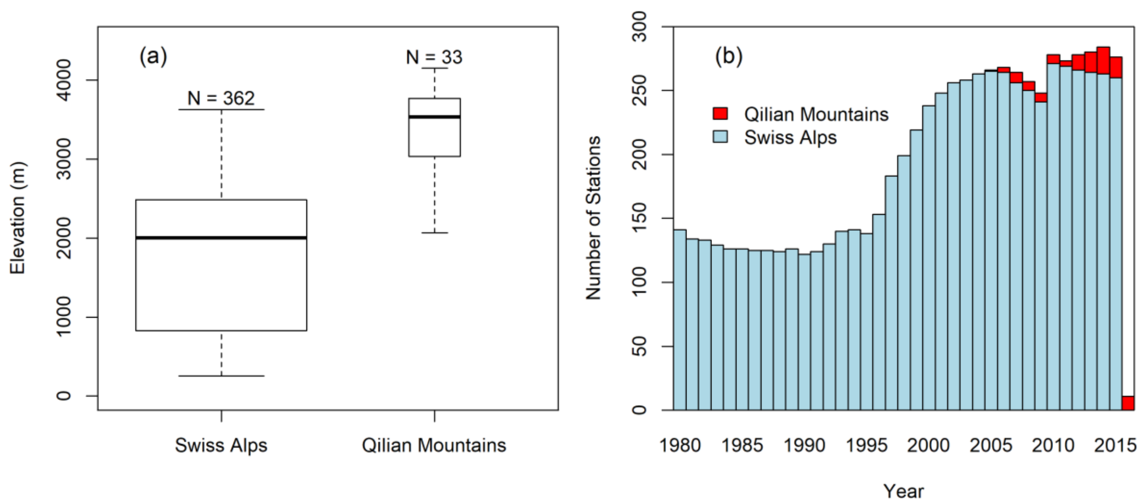

Figure 2 Elevation distribution of observation stations (a), number of observation stations (N) used in different years (b).

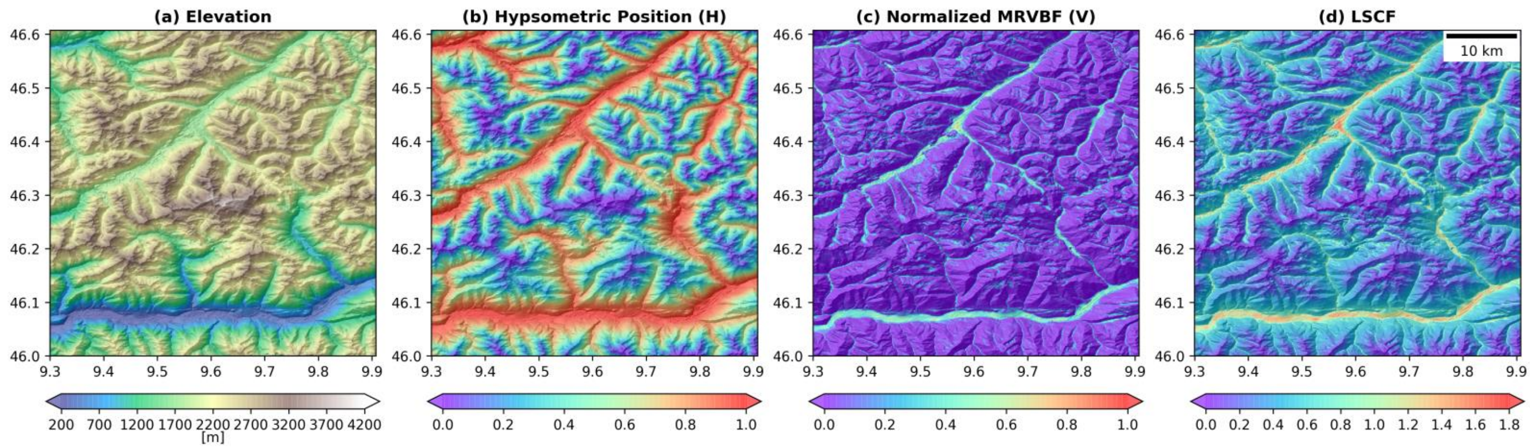

Figure 9 Spatial variation of elevation (a), hypsometric position (b), normalized MRVBF (c) and *LSCF* (d) in selected slope terrain.

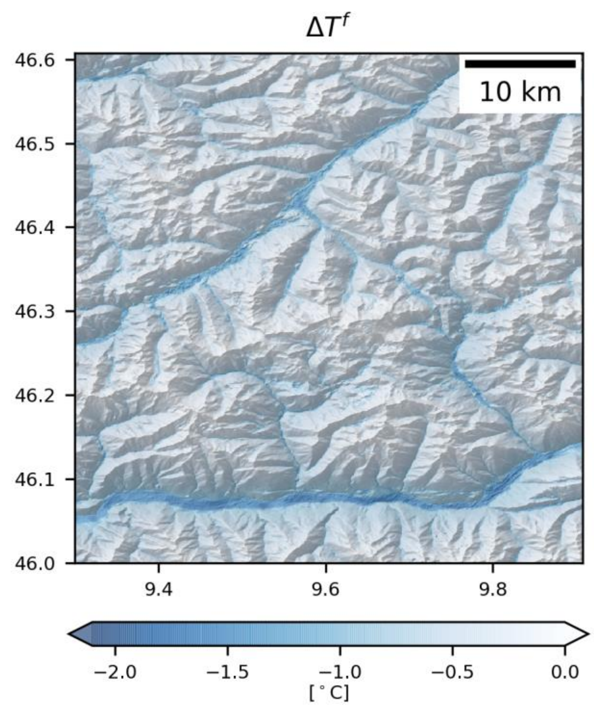

Figure 13 Fine-scale of land-surface influence (ΔT^f) for the test area.

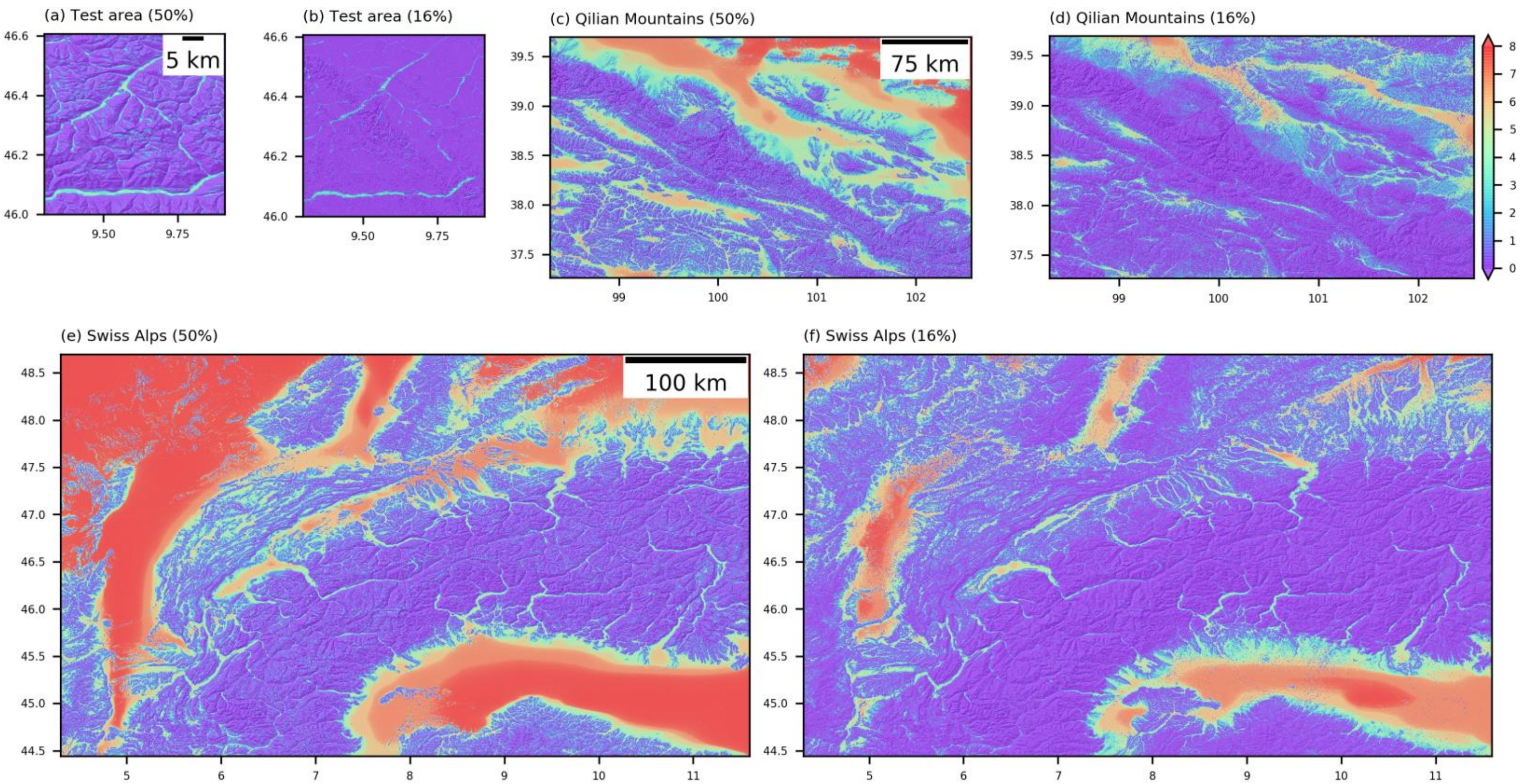

Figure A2 Original MRVBF in the test area, Swiss Alps and the Qilian Mountains by using slope threshold of 50% and 16%.

Table 3. Comparison of observations against reference methods of REF2 and REF3.

Station	Location				**Observation period**	REF2		REF3	
	Lat (°)	Lon (°)	Ele (m)	Topography		RMSE	BIAS	RMSE	BIAS
COV	46.4180	9.8212	3351	Peak	**01/1998–12/2015**	1.01	0.24	1.63	-0.41
DDS	38.0142	100.2421	4147	Peak	**10/2007–10/2009**	1.34	0.56	2.38	-1.05
BEV1	46.5487	9.8538	2490	Peak	**09/1997–12/2015**	1.22	0.54	1.41	0.04
EBO	37.9492	100.9151	3294	Slope	**06/2013–12/2014**	3.31	2.41	1.87	0.43
SIA	46.4323	9.7623	1853	Valley	**01/1980–12/2015**	2.44	1.14	1.65	0.50
SAM	46.5263	9.8789	1756	Valley	**01/1980–12/2015**	3.85	1.95	2.81	1.39

Specific comments:

Page 1, Line 18: Change "oder" to order.

We corrected the typo.

Page 6, Line 7: Include citation for "degree of valleyness."

Should it be Line 11? We named “degree of valleyness” (*V*) and descried by the normalized multiresolution index of valley bottom flatness (MRVBF) (Gallant & Dowling 2003). In this case, we added the citation of Gallant & Dowling (2003) before Eq. 10 rather than here. We hope you agree.

Page 13: Many of the references are missing doi numbers. Please include these.

Thank you for pointing this. The doi numbers will be added in a revised submission.

Page 25: I am unsure what you mean by “a quality of points visual.”

Sorry for the typo, it should be *“a quantity of points visual”*.

References:

Daly, C., Gibson, W., Taylor, G., Johnson, G. & Pasteris, P. 2002. A knowledge-based approach to the statistical mapping of climate. *Climate Research* 22 : 99–113. DOI: 10.3354/cr022099

Daly, C., Taylor, G.H., Gibson, W.P., Parzybok, T.W., Johnson, G.L., Pasteris, P.A. & others 2000. High-quality spatial climate data sets for the United States and beyond. *Transactions of the ASAE-American Society of Agricultural Engineers* 43 : 1957–1962.

Gallant, J.C. & Dowling, T.I. 2003. A multiresolution index of valley bottom flatness for mapping depositional areas. *Water Resources Research* 39 : n/a–n/a. DOI: 10.1029/2002WR001426

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G. & Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International journal of climatology* 25 : 1965–1978.

Thornton, P.E., Running, S.W. & White, M.A. 1997. Generating surfaces of daily meteorological variables over large regions of complex terrain. *Journal of Hydrology* 190 : 214–251. DOI: http://dx.doi.org/10.1016/S0022-1694(96)03128-9