Orographic modulation and elevation dependence of regional fine scale precipitation change signals - European examples

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objective

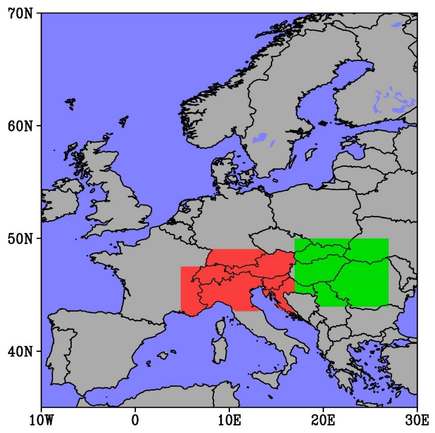
This study investigates the greenhouse gas-induced winter and summer precipitation change signals over the Alps and the Carpathian Region with special focus on topographical effects and underlying processes.

experimental design

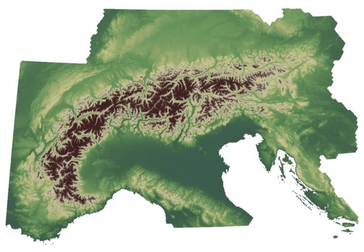
High number of regional climate model (RCM) experiments have been accomplished over different sub-regions of the globe in the framework of the international initiative called the COordinated Regional Downscaling Experiment (CORDEX). Being the European branches of the CORDEX program: **EURO-CORDEX** and **Med-CORDEX** provide RCM simulations targeting Europe (for Med-CORDEX: being the Mediterranean region in focus) at grid resolutions of 0.44° (medium resolution) and of 0.11° (high resolution). Detailed investigation of ensembles of driving GCM and nested RCM simulations for the late 21st century with respect to late 20th century from the CMIP5, EURO-CORDEX, and Med-CORDEX experiments are presented at **high resolution (0.11°)**, with a special focus on the **Alps** and the **Carpathian Region**. Present work gives an overview on how the fine-scale RCM downscaling can modulate the GCM-produced precipitation change signal under the **RCP8.5** scenario in future climate projections over the regions of interest. The RCM ensemble consists 6 models in total: **ALADIN, CCLM, RCA4, RACMO, REMO** and **RegCM**. Driving fields were provided by the following GCMs: **CNRM-CM5, EC-EARTH, HadGEM2-ES** and **MPI-ESM-LR**.

results

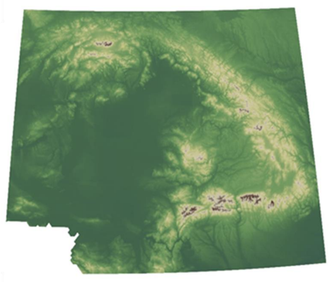
1 Fields of interest



The regions of interest within Europe. The region of the **Alps** (red) and the **Carpathian Region** (green).

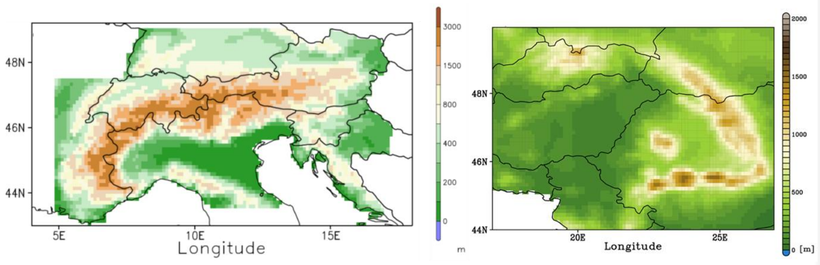


Alpine Region



Carpathian Region

Orographical representation of the analysis regions based on GTOPO30 database at 1′ horizontal resolution (~2 km).



Analysis regions and topography (on a common 0.11° grid, ~ 12 km) over the Alps and the Carpathian Region. Note that the scales are different for each region.

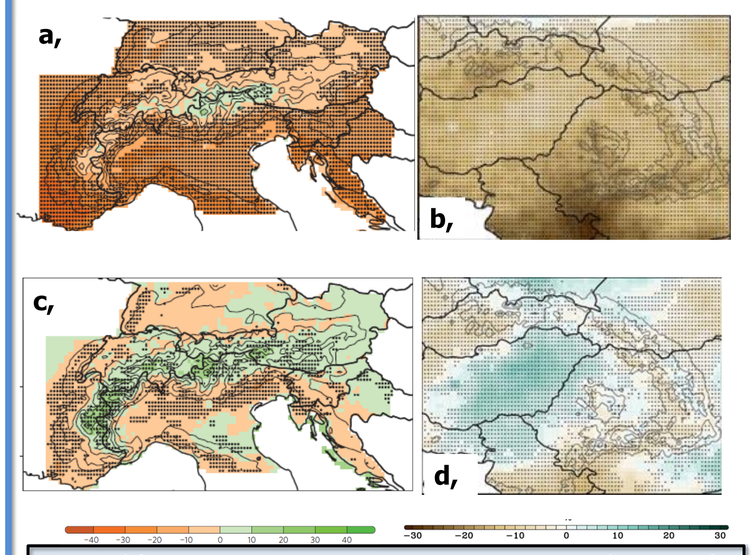
2 Precipitation change (DS and PI)

Downscaling Signal

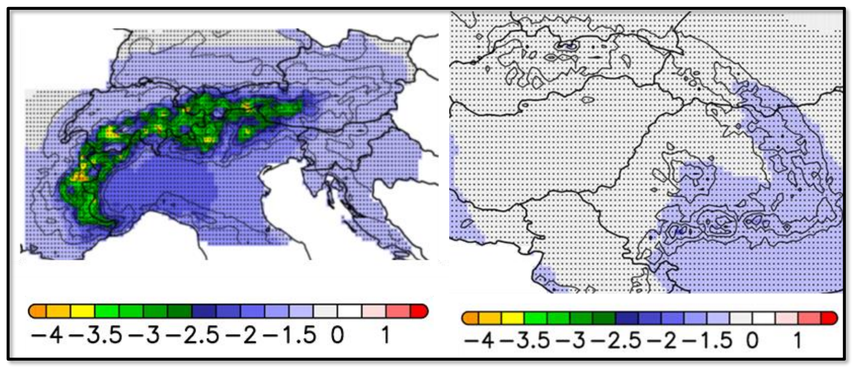
$$\mathrm{DS}(\Delta P) = (\Delta P_{\mathrm{RCM}_i} - \Delta \bar{P}_{\mathrm{RCM}_i}) - (\Delta P_{\mathrm{GCM}_j} - \Delta \bar{P}_{\mathrm{GCM}_j})$$

Potential Instability

$$\mathrm{PI} = \theta_{e500} - \theta_{e850}$$

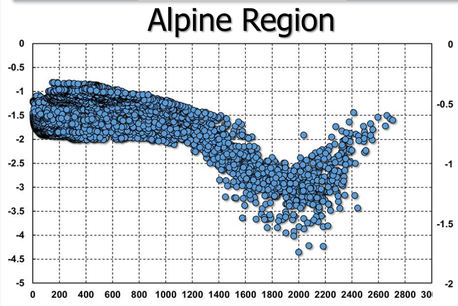


Ensemble average summer precipitation change (a, and b, panels) and DS (c, and d, panels) for 2070-2099 with respect to 1976-2005. Changes are given in %. Dotting indicates areas where at least 4 out of 6 RCMs agree on the sign of the signal (Giorgi et al. (2016) and Torma and Giorgi (2020)).

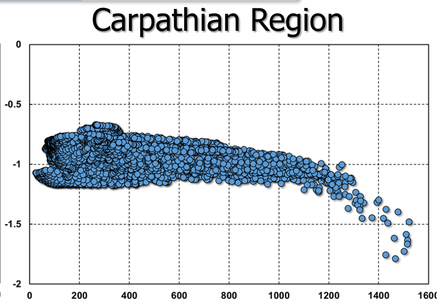


Change in summer mean potential instability index with inclusion of moistureover both regions. Noting that the same colorscale is applied. The change was computed for 2070-2099 with respect to the reference period of 1976-2005. Dotting indicates region where most of the RCMs (4 out of 6) agreed on the sign of the change, thus those regions highlight where our findgins are robust. Units are °C. Thin contour lines represent topography with intervals of 500 meters. For further information read Giorgi et al. (2016) and Torma and Giorgi (2020).

Alpine Region

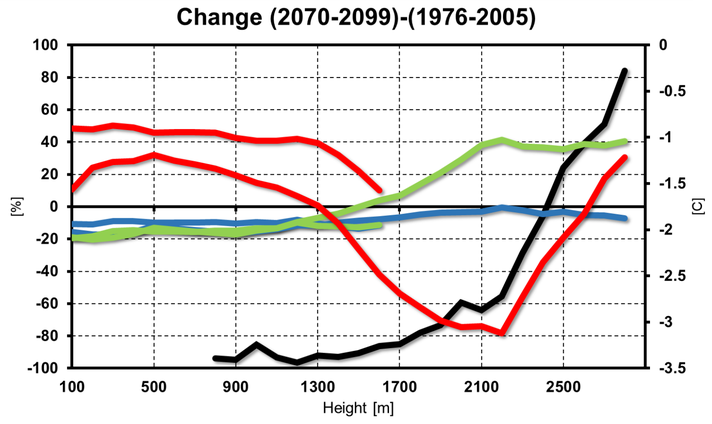


Carpathian Region



The change of PI (y-axis) based on the actual height (x-axis). The results are reported for the Alps (left) and for the Carpathians (right) The PI change is given in °C, while the height is given in meters.

Change (2070-2099)-(1976-2005)



The mean change of snow based on 5 RCM simulations and the mean change of precipitation (also convective precipitation) along with the change of PI (values indicated on the right side of y-axis) and their actual mean height (x-axis). The changes related to precipitation is given in % and the PI change is given in °C, while the height is given in meters with intervals of 100 meters. (REMO model is absent as snow data was not available at time of present analyses.)

summary

- **Topographically induced fine scale modulation of the precipitation change signal is mostly of thermodynamical in summer (associated with high elevation convection) over the Alps and the Carpathians, and associated with snow cover feedback**
- **Topographically induced fine scale precipitation signal is mostly of dynamical nature in winter**
- **Elevation and expansion of mountains play key roles in such processes**
- **High resolution representation of topography in climate models is crucial for the provision of fine scale precipitation projections in mountainous regions**

References
Giorgi F., Cs. Torma, E. Coppola, N. Ban, C. Schär, S. Somot (2016): Enhanced summer convective rain at Alpine high elevations in response to climate warming., *Nature Geoscience*, 9:584-589, doi:10.1038/ngeo2761
Torma Cs, Giorgi F. (2020): Onthe evidence of orographical modulation of regional fine scale precipitation change signals: The Carpathians. Atmos Sci Lett.;e967. https://doi.org/10.1002/asl.967

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