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Alpine temperature changes: features and feedbacks
Switzerland 1981-2017

Objectives

The two main research questions we want to address are:

1) Are temperatures changing at a different rate depending on elevation?
2) What are underlying driving mechanisms of elevation dependent temperature changes?

Study area and data sources

- daily resolution information on mean, maximum and minimum temperature, snow depth, cloud cover, global radiation, absolute air humidity, sunshine duration and atmospheric pressure (reduced to sea level)
- all stations of the Swiss monitoring network (+ German high elevation station Zugspitze) recording at least one of the selected climatological variables for at least 32 out of the 37 years (1981-2017)
- climate data from 94 meteorological stations, including 28 stations with homogenized temperature data in daily resolution (Fig.1)

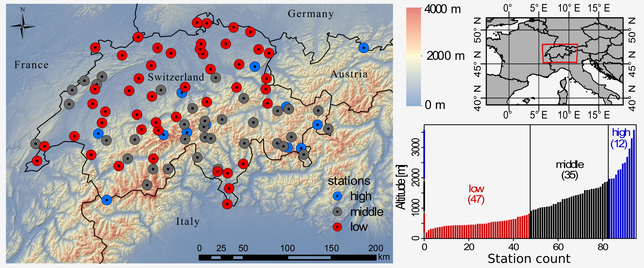
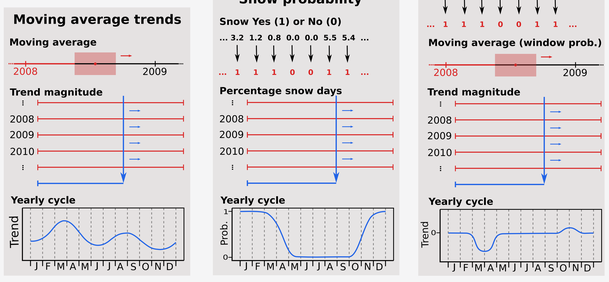


Fig.1: Topographic map of study area (left), setting within Europe (top right) and elevation distribution of stations with number of stations of each elevation category (lower right)

Methods

- robust linear Sen´s slope estimator and Mann-Kendall trend test to assess trend magnitude and significance
- aggregation of data by applying 30-Day moving average filter



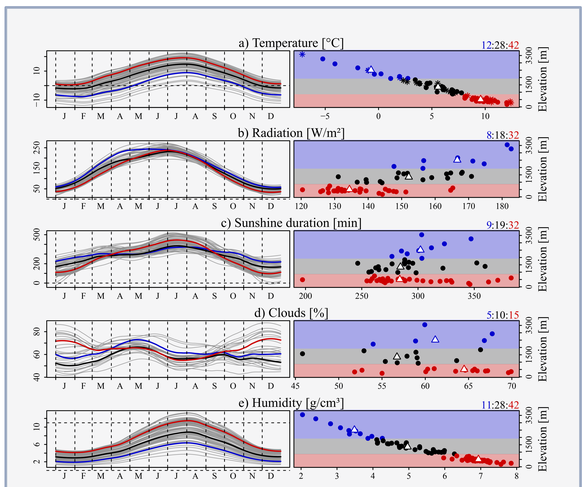


Fig.2: Yearly cycles of moving average values (left) and height dependency of annual averages (right). Solid dots indicate annual averages of individual stations, triangles the average of each elevation category. Stars in a) denote stations with homogenized temperatures data. Number of stations of each category noted top right.

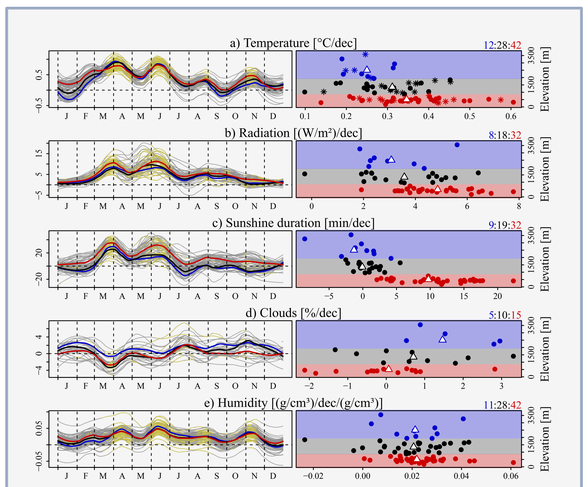


Fig.3: Yearly cycles of trend magnitudes (left) and height dependency of annual averages magnitudes (right). Solid dots indicate annual averages trend of magnitudes of individual stations, triangles the average of each elevation category. Stars in a) denote stations with homogenized temperatures data. Days with significant trend marked yellow (alpha = 0.05). Number of stations of each category noted top right.

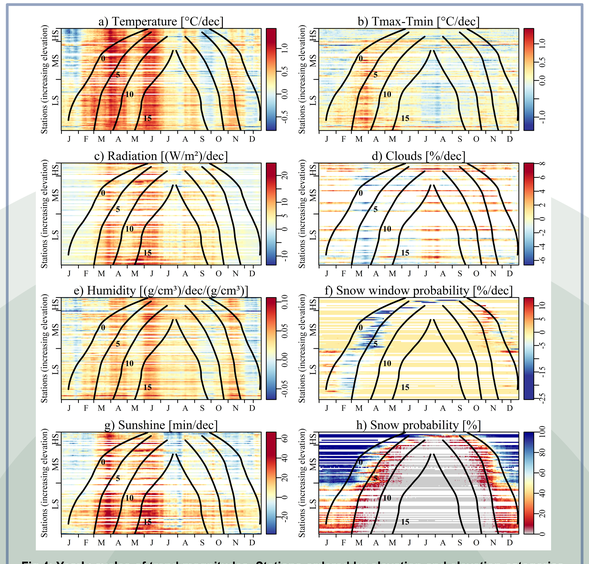


Fig.4: Yearly cycles of trend magnitudes. Stations ordered by elevation and elevation categories high (HS), middle (MS) and low (LS) marked. Solid lines denote temperature isotherms (°C).

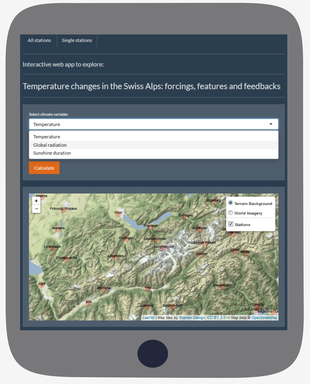
Results and Discussions

- annual average temperature trends are positive for all stations investigated (Fig.3a)
- temperature trends tend to be stronger the lower the elevation (autumn and winter)
- positive trends in global radiation (solar brightening) (Fig.3b)
- distinct elevation-based differences in trends sunshine duration: changes in low altitude stratus clouds? Lower life time? (Fig.3c)
- reduction of cloud cover during springtime: circulation-driven changes? (Fig.3d, 4d)
- changes clouds cause differences in temperature trends depending on time of the day (Fig.4b,d)
- no clear temperature signal arising from snow/ice albedo feedback
- increase water vapor content: during winter enhanced water vapor feedback within decoupled near ground air layer? (Fig.3e)
- increased vertical mixing end of spring and summer overrides elevation-based differences in temperatures trends

Conclusions

- temperatures in Switzerland change at a different rate depending on elevation with stronger warming at lower elevations (autumn and winter)
- we attribute this difference in temperature trends to elevation-based differences in trends of incoming global radiation and strength of water vapor feedback

Reusability and accessibility



- Interactive web app to explore alpine climate change:

Web App

- R package for analysis of alpine climatological data using moving average trend statistics: https://github.com/ERottler/alptempr

Acknowledgements

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