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Is it possible to characterize the climate of an Alpine region by means of synoptic circulation types?

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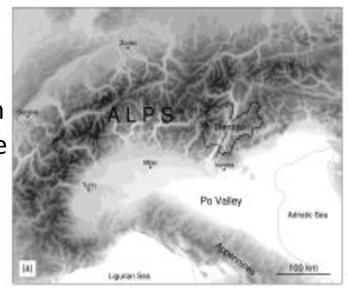
Objectives of this study

The aim of this study is quantify the relation between circulation types and the climate of an Alpine region. In fact, even though it has long been known that synoptic circulation types determine the main features of weather and climate, this relation has not yet been comprehensively analyzed for an Alpine region considering more than one atmospheric variable and a relevant number of statistical indices.
The study area is Trentino, a mountainous area located in the South-Eastern Alps in Italy (6212 km^2, see map to the left).

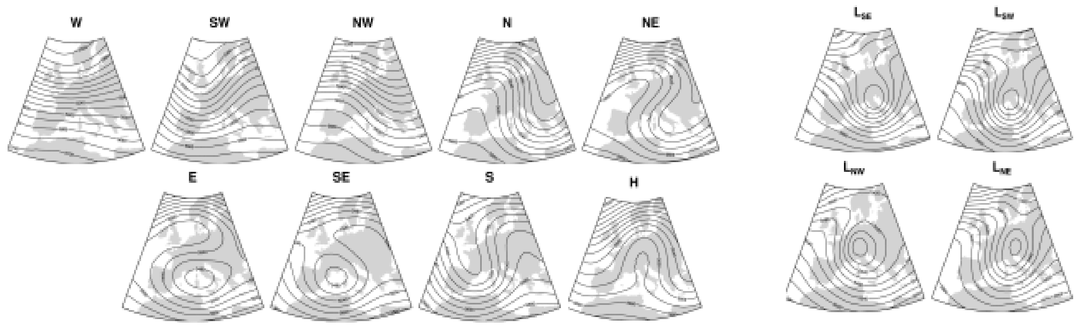


Why?

- For downscaling climatic variables from large-scale patterns reproduced by general circulation models
- To build the scientific framework necessary to develop a long-range probabilistic forecasting system based on analogue circulation types, expected to have high skill at regional and local scale for long lead times.

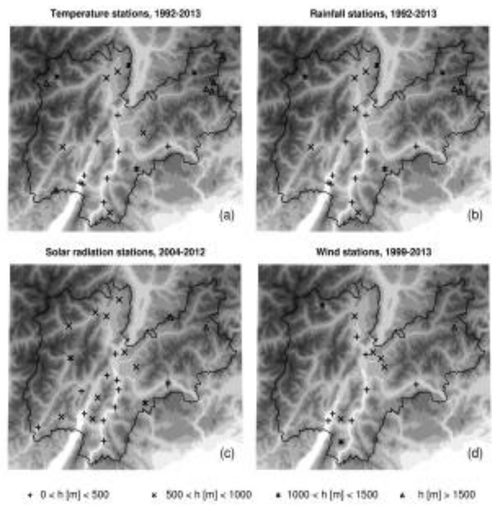
Circulation types

The synoptic circulation classification method developed by Beck (2000) known as *Grosswettertypes* was chosen for this study, and applied over the Alpine region for 4 distinct vertical levels (Z500, Z700, Z850, SLP). The low-pressure class was subdivided in 4 sub-classes depending on the position of the low pressure system with respect to Trentino. In the figure composites of 500-hPa geopotential height for the synoptic circulation types are shown for the period 1992–2013.



Meteorological data

The climate of Trentino is described by means of meteorological stations data. A database of temperature, rainfall, solar radiation and wind measurements was composed and quality controlled. The figure shows the location of the stations and the analyzed periods which depend on data availability.



Some of the findings…

Do synoptic circulation types produce distinct climate anomalies over Trentino?

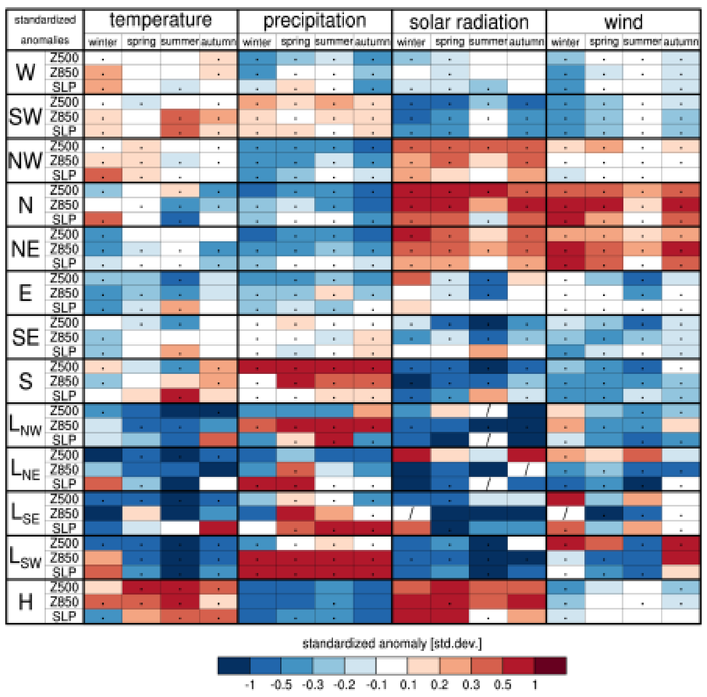
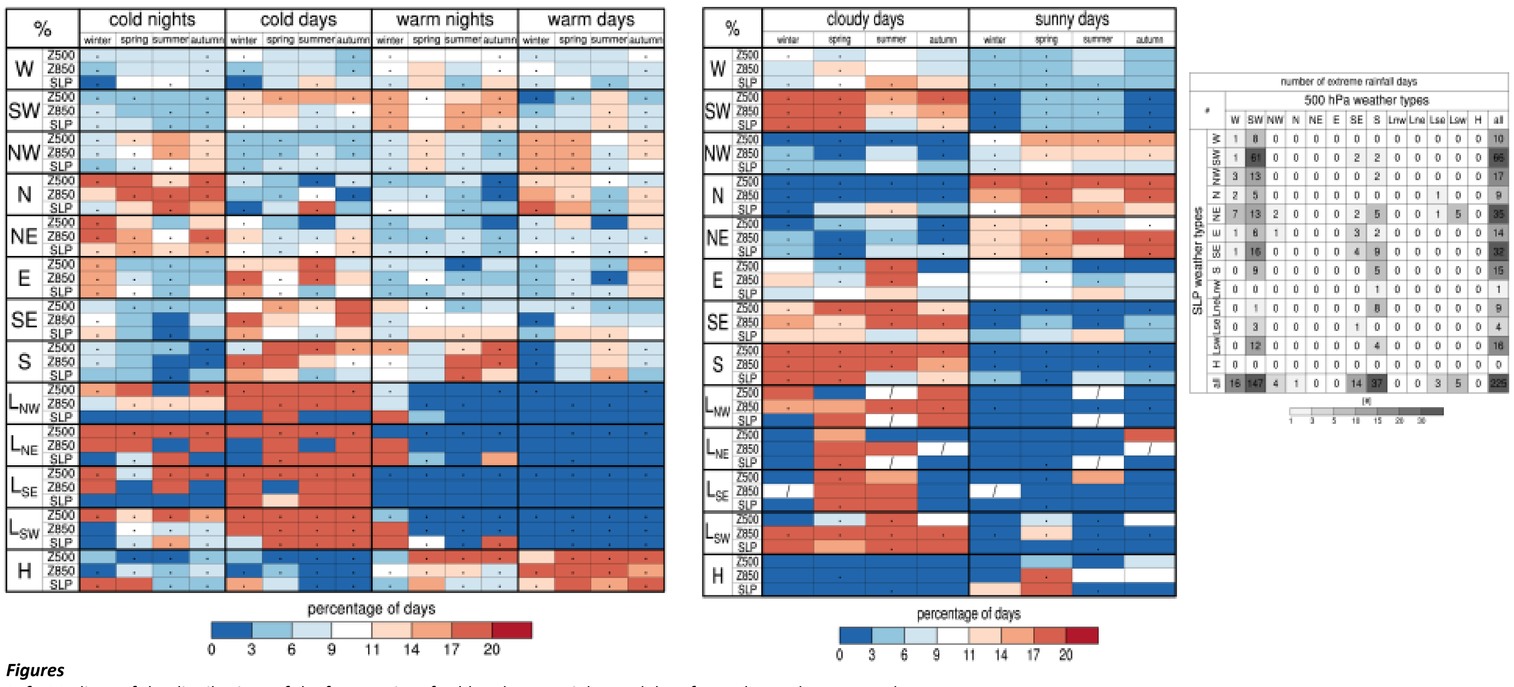


Figure: *Medians of the distributions of the seasonal standardized anomalies of mean daily temperature, daily rainfall, daily solar irradiation and mean daily wind for each weather type and season. Dots mark the anomalies which are statistically significant for more than one-third of the stations.*

Is the occurrence of extreme meteorological events related to synoptic circulation types?



Figures
Left: *Medians of the distributions of the frequencies of cold and warm nights and days for each weather type and season.*
Center*: medians of the distributions of the frequencies of cloudy and sunny days for each weather type and season.*
For left and center figures the climatological frequency is 10%. Dots mark the synoptic patterns whose radiation anomaly is statistically significant for more than one third of the stations.
Right: *Medians of the number of extreme rainfall days for SLP and 500 hPa weather types and their combinations.*

Does the predictive skill of a classification method depend on the level of the circulation types?

The predictive skill of the synoptic circulation classification method was investigated
By computing the explained variance (EV) and Brier Skill Score (BSS) for each vertical leve and season.

$$EV = \frac{\sum_{t=1}^{T} N_t(\bar{a}_t - \bar{a})^2}{\sum_{d=1}^{D}(a_d - \bar{a})^2}$$

a atmospheric variable
$t = 1,\ldots,T$ circulation types
N_t number of days in type t
$\bar{a}_t$ mean of a in type t
$\bar{a}$ seasonal mean of a
$d = 1,\ldots,D$ all days of season

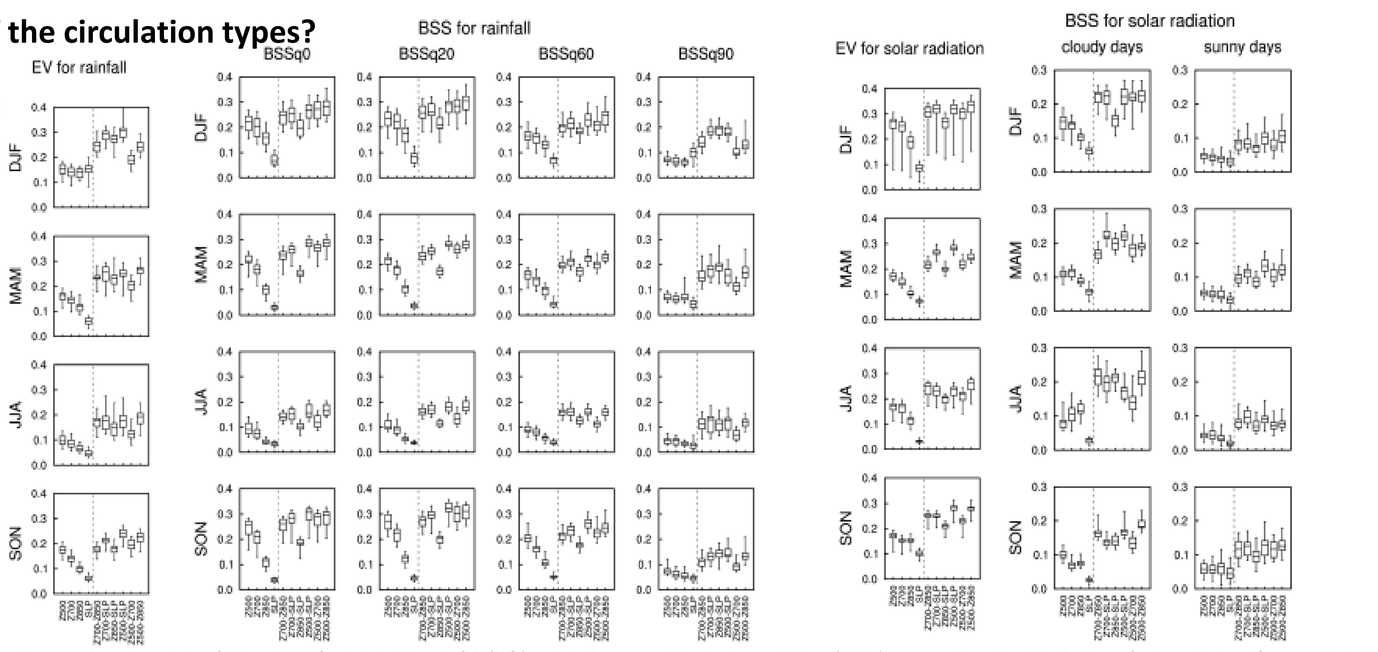
$0 \le EV \le 1$
the larger the better

$$BSS = \frac{\frac{1}{D}\sum_{t=1}^{T} N_t(f_t - f_c)^2}{f_c(1-f_c)}$$

For binary variable like occurrence of extreme event.

f_t empirical frequency of event in type t
f_c climatological frequency of event

$0 \le BSS \le 1$
the larger the better,
BSS=0 if f_t=f_c for each type



Figures *show box-plots of EV and BSS for total daily rainfall (**left**) and daily accumulated solar radiation (**right**) representing the distribution of values derived from each station.*

Conclusions

- ✓ Distinct seasonal anomalies of mean daily temperature, total daily rainfall, daily solar irradiation and mean daily wind intensity are associated with most circulation types. Their magnitude varies not only among weather types, but also within the same type for different levels and seasons.
- ✓ Extreme meteorological events occur with preferential circulation types: the frequency of occurrence of extremes for each synoptic pattern rarely coincides with the climatological value.
  Examples: (1) most of extreme rainfall days occur with the SW circulation at 500 hPa. Such configuration takes place frequently and produces more than 50% of the total rainfall in every season and the largest daily rainfall totals. (2) the N, NW and high pressure circulations cause generally a number of warm days larger than the climatology, whereas with low pressures, southerly and easterly weather types the number of warm days is smaller than average.
- ✓ The mesoscale mechanisms resulting from the interaction of the large-scale flow with the local orography are of fundamental importance in determining the character of the weather associated with each synoptic pattern, and strongly influence the climate of Trentino**.**
- ✓ The differences in predictive skill between distinct vertical levels over Trentino are large, and they are generally comparable in magnitude to those between different atmospheric variables and seasons for the same level. Thus, the investigation of the optimal level for a certain atmospheric variable and season is of primary importance for any application of synoptic classification schemes.
- ✓ The vertical level of the classification scheme providing the highest predictive capability depends on the season and the atmospheric variable. However, circulation types at 500 hPa show a predictive skill significantly higher than lower levels for total daily rainfall, daily solar irradiation and daily temperature range in almost all seasons.
- ✓ The predictive skill associated with combinations of circulation types at two different levels results significantly larger than that of single level classifications for all climatic variables and seasons, with the exception of the BSS values for the exceedance of low rainfall thresholds in the colder seasons. However, the differences in skill between the combinations are very small, and it is not possible to identify an optimal combination of levels, not even for the same atmospheric variable and season.

A more detailed description of this study can be found in the following 2 papers:

Panziera, Giovannini, Laiti and Zardi, 2015: The relation between circulation types and regional Alpine climate. Part I: Synoptic climatology of Trentino. *Int. Jour. Climatology*, 2015, doi: 10.1002/Ijoc.4314
Panziera, Giovannini, Laiti and Zardi, 2015: The relation between circulation types and regional Alpine climate. Part II: The dependence of the predictive skill on the level of the classification method for Trentino. *Int. Jour. Climatology*, accepted.