Characterizing large-scale circulations driving extreme precipitation in the Northern French Alps

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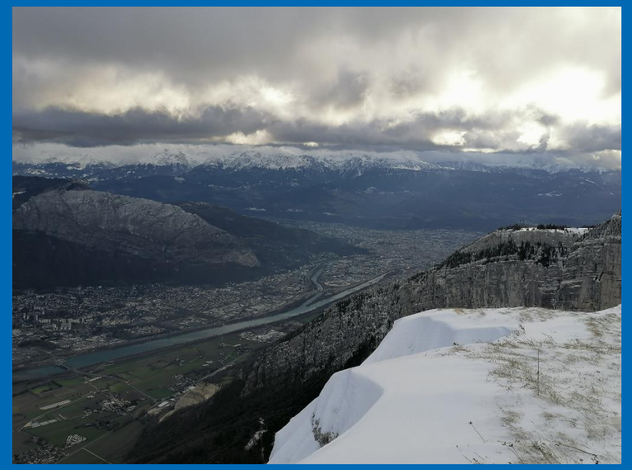

The Isère River downstream Grenoble, Northern French Alps

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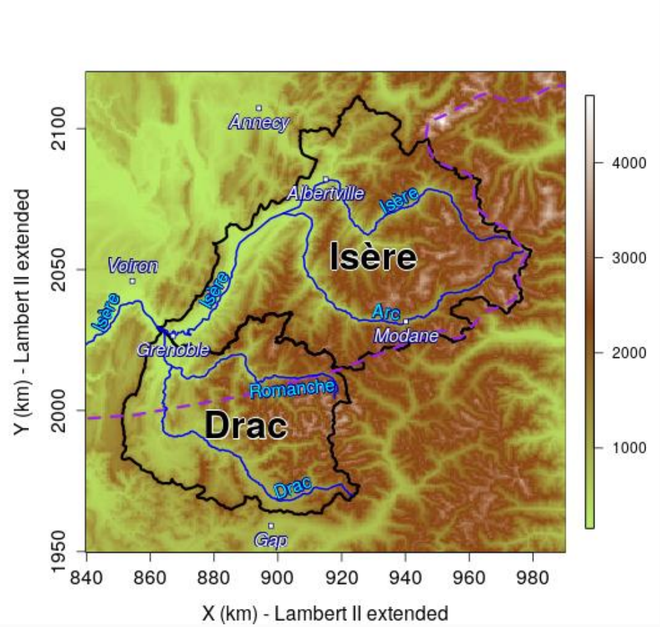
Data & Region of study

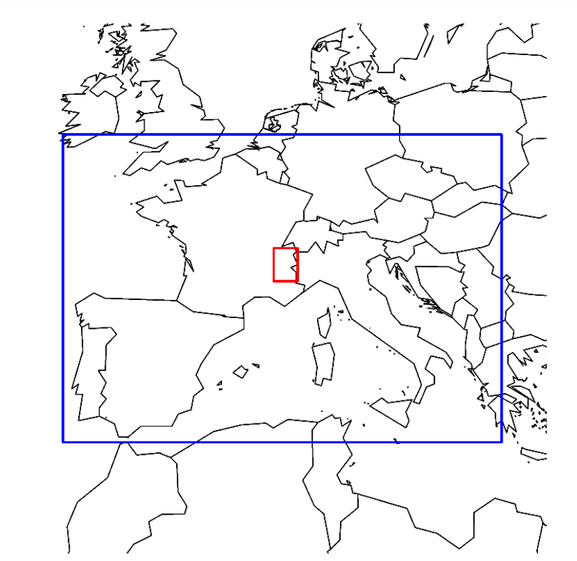


- **Isère** River catchment at Grenoble: *5800 km², altitude from 200m to 3900m.*
- **Drac** River catchment at Grenoble**re :** *3600 km², altitude from 200m to 4100m.*

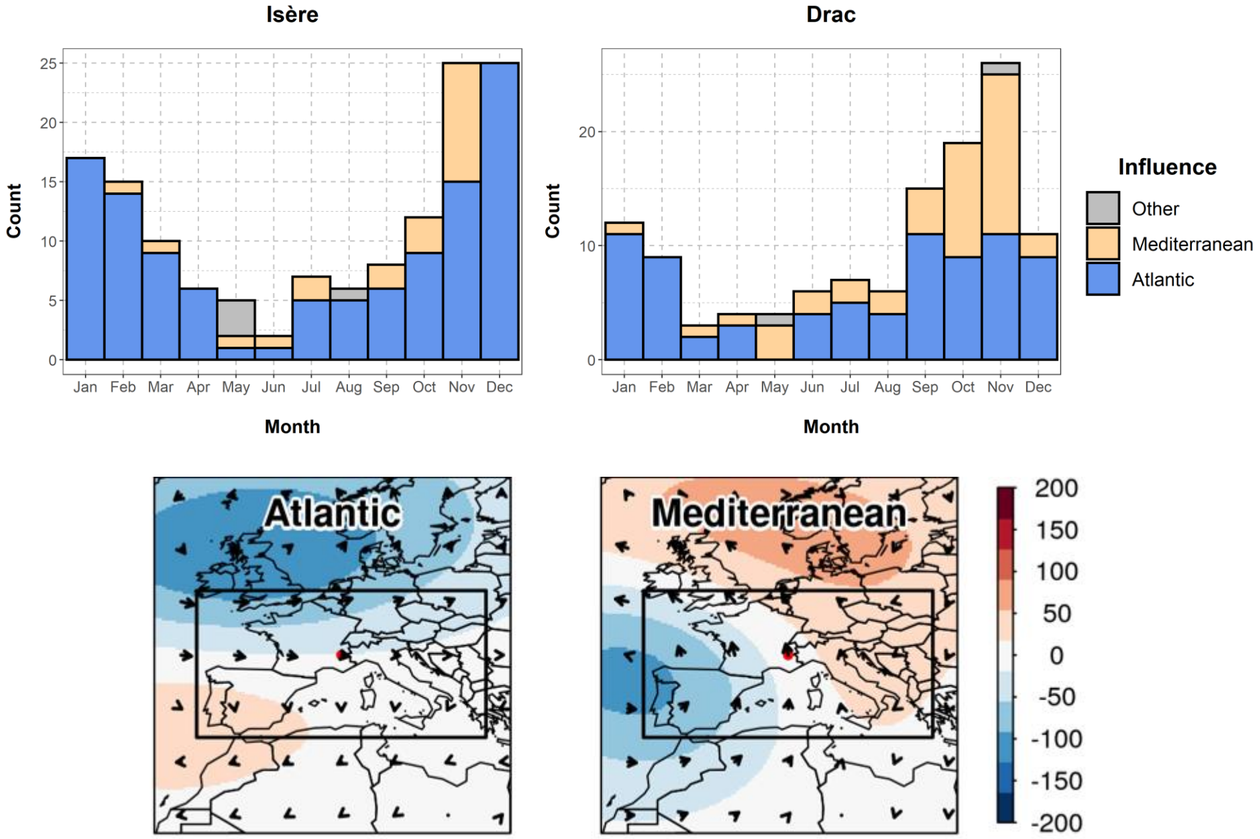
- Daily catchment precipitation obtained with the **SPAZM reanalysis** *(Gottardi etal., 2012)*

- **1% largest 3-day catchment precipitation from 1950 to 2017: EPS (Extreme Precipitation sequences)**

- **Daily 500 hPa geopotential height over Western Europe** (blue rectangle) extracted from the **ERA5** reanalysis *(Hersbach et al., 2020).*



Context



Classification of Garavaglia et al. (2010)

- EPS in the Northern French Alps are mainly associated with **Atlantic and Mediterranean circulations.**

- Atlantic and Mediterranean circulation are **very frequent in the climatology**: respectively 44% and 26% of 3-day sequences in the period 1950-2017.

⇒ **What characterizes the Atlantic/Mediterranean circulations driving EPS in the Northern French Alps in comparison to 'random' Atlantic/Mediterranean circulations?**

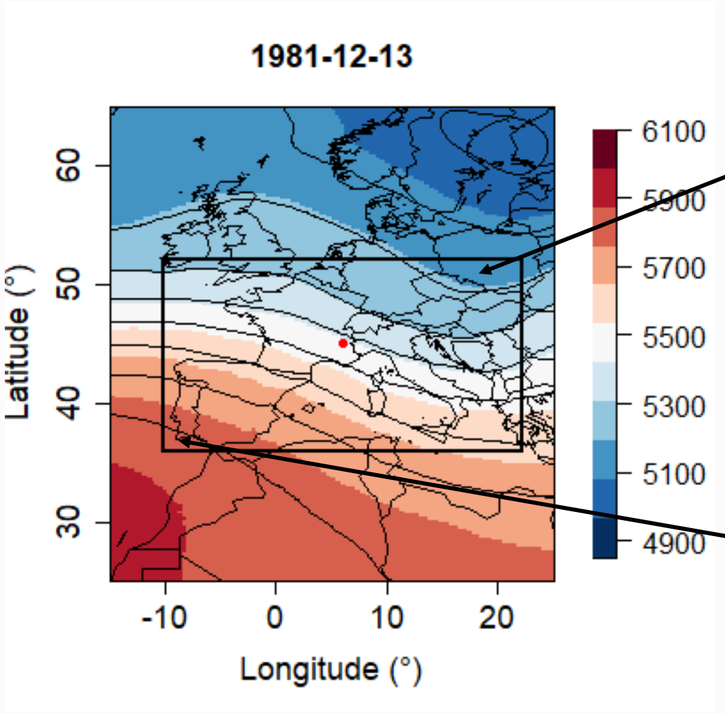
⇒ Computation of **4 atmospheric descriptors** characterizing every daily 500 hPa geopotential height field *(introduced in Blanchet et al., 2018 & Blanchet and Creutin, 2020)*

Maximum Pressure Difference (MPD)

MPD represents **the range of geopotential heights** (in meters) over Western Europe.
Let z_{jk} denotes the 500 hPa height of grid point s_j and day t_k. MPD_k is defined as:

$$\boldsymbol{MPD_k = max_j(z_{jk}) - min_j(z_{jk})}$$

MPD reflects **the intensity of the centers of action** (that is, the intensity of the low and the high pressure systems).



Min(Z500) = 5146 m

Max(Z500) = 5811 m

Example of December 13, 1981:
MPD = 5811 – 5146 = 665 m

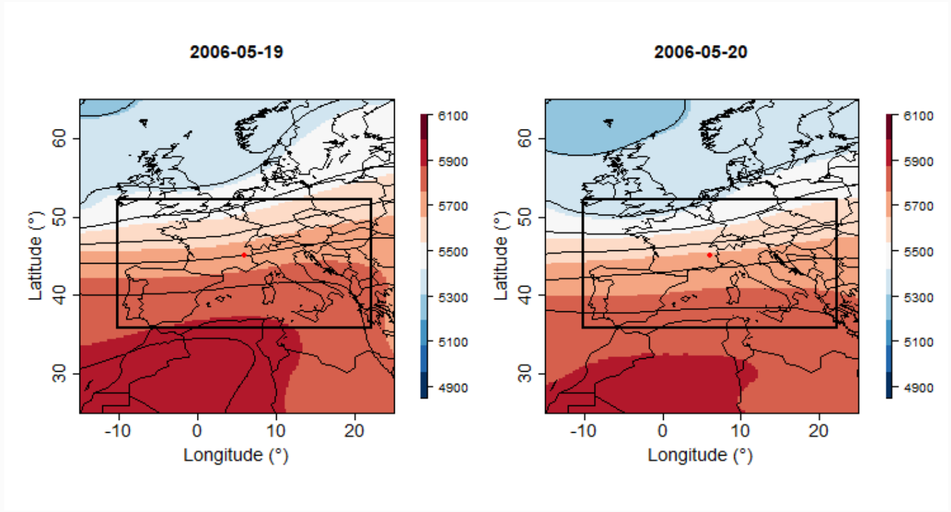
Celerity

The celerity characterizes **the stationarity in geopotential shape between two consecutive days.**
The celerity is based on analogy: it is defined as the **Teweles-Wobus score** *(Teweles & Wobus, 1954)* between day t_k and day t_{k-1} .

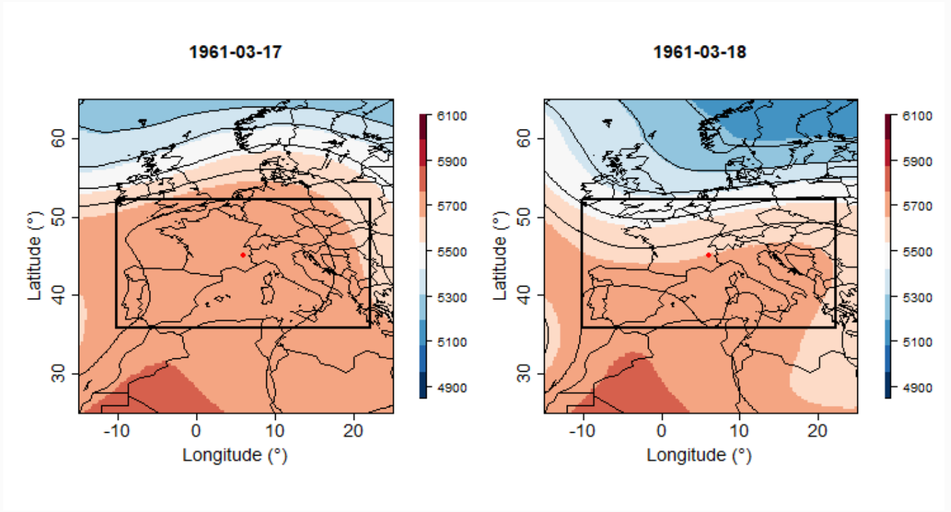
$$cel_k = TWS_{k-1,k}$$

*The **TWS** measures the similarity in shape between geopotential height fields, based on North-South and West-East gradient.*

The celerity reflects **the degree of stationarity in flow direction.**



Low celerity

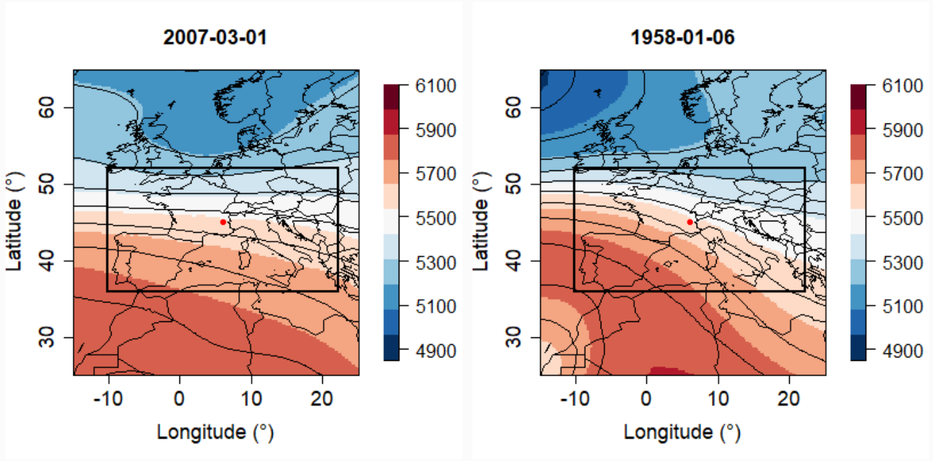


Large celerity

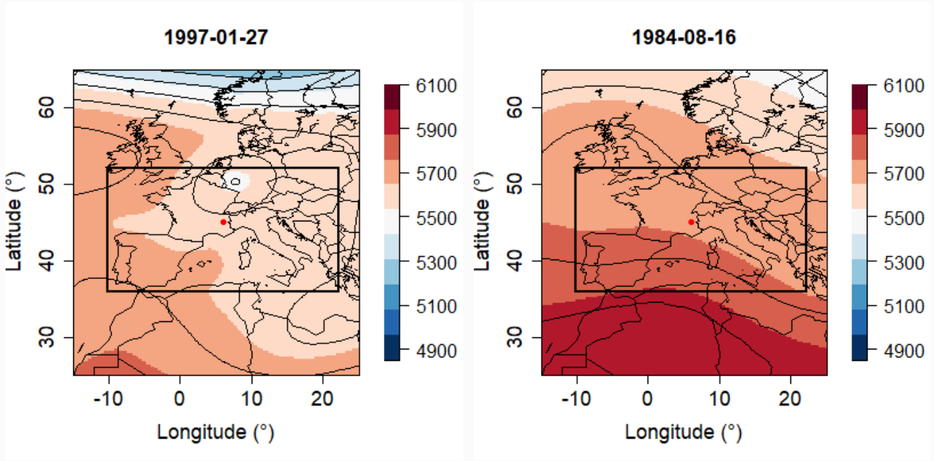
Singularity

The singularity is based on analogy. The singularity of day t_k is defined as the mean **Teweles-Wobus score** between day t_k and its 124 (0.5%) closest analog days within the period 1950-2017:

$$sing_k = \frac{1}{Q} \sum_{k=1}^{k=Q} TWS_{k,(q)}$$



2007-03-01 and its 50th analog day. ***Low singularity.***



1997-01-27 and its 50th analog day: ***Large singularity.***

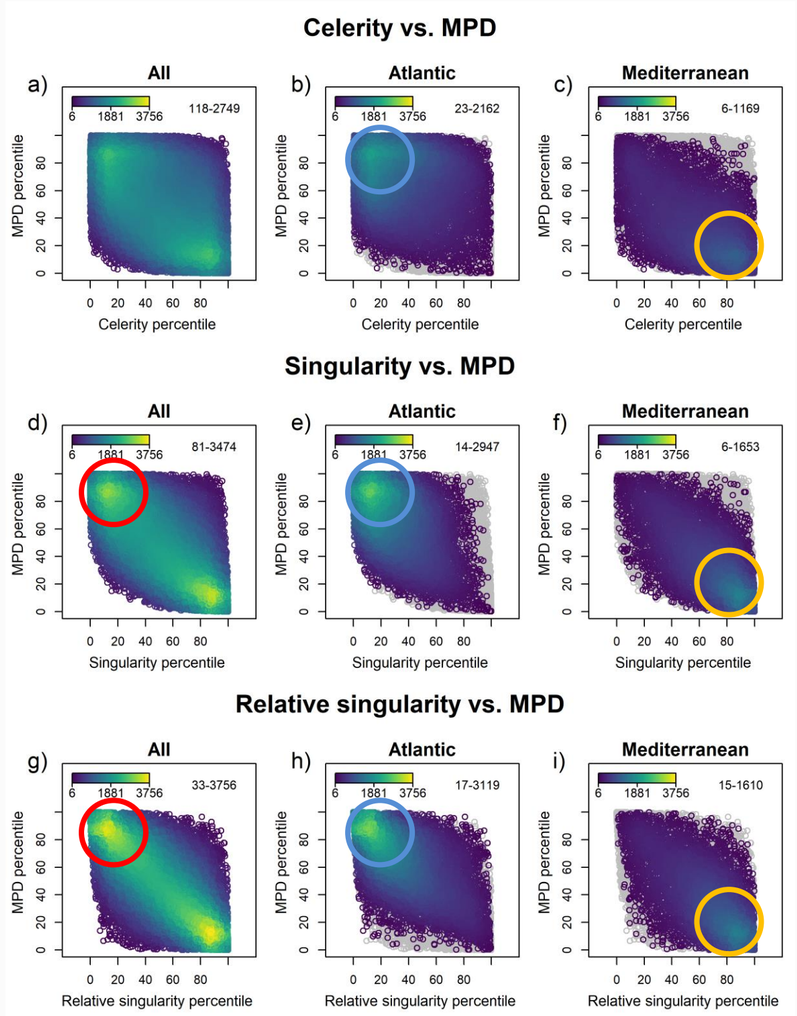
Relative Singularity

The relative singularity is based on analogy. The relative singularity of day t_k is defined as the singularity divided by the **Teweles-Wobus score** to its 124th analog. It measures **the similarity to the close analogs relatively to the farther analogs.**

$$rsing_k = \frac{sing_k}{TWS_{k,(Q)}}$$

The singularity and relative singularity measure whether or not a flow direction is closely reproduced in the 1950-2017 climatology.
Low singularity and low relative singularity => almost similarly reproduced

Characterizing Atlantic and Mediterranean circulations



Yellow area = large density of 3-day sequences.

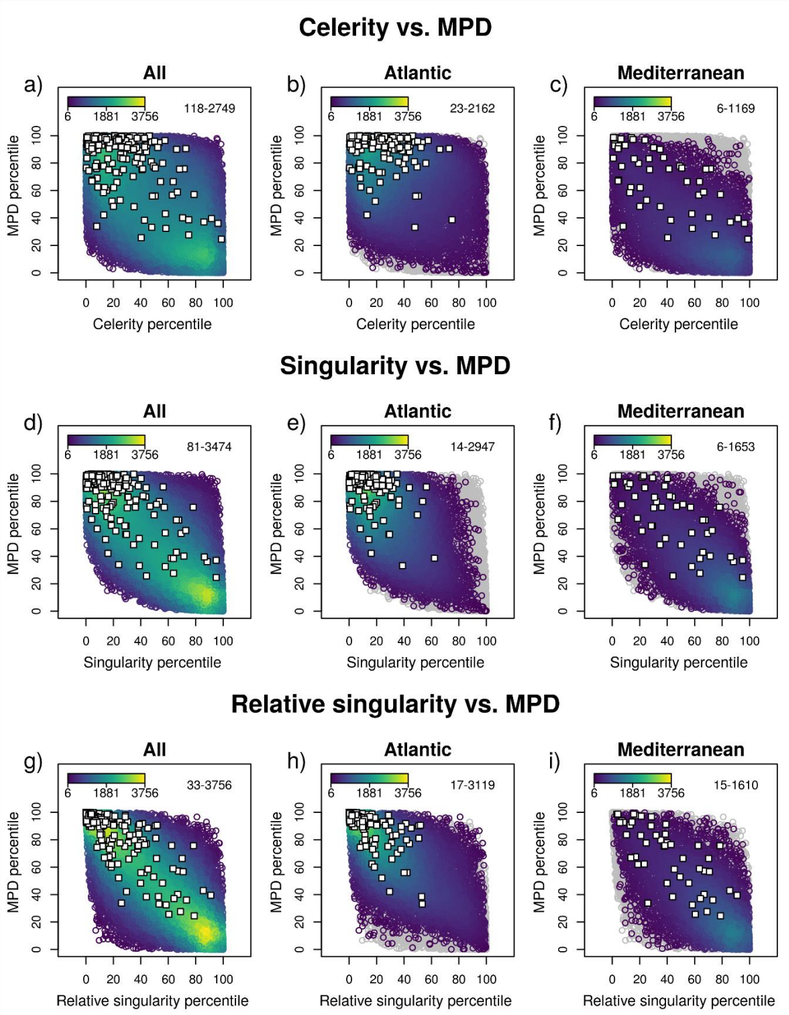
- Geopotential shapes that are closely reproduced in the climatology tend to be associated to pronounced centers of action

- Atlantic circulations tend to feature **pronounced and stationary centres of actions** (high MPD and low celerity), with geopotential shapes that are **almost similarly reproduced in the climatology** (low singularity and relative singularity).

- **Mediterranean circulations tend to feature flatter and non-stationary geopotential shapes** (low MPD and high celerity) **that are hardly reproducible** (high singularity and relative singularity).

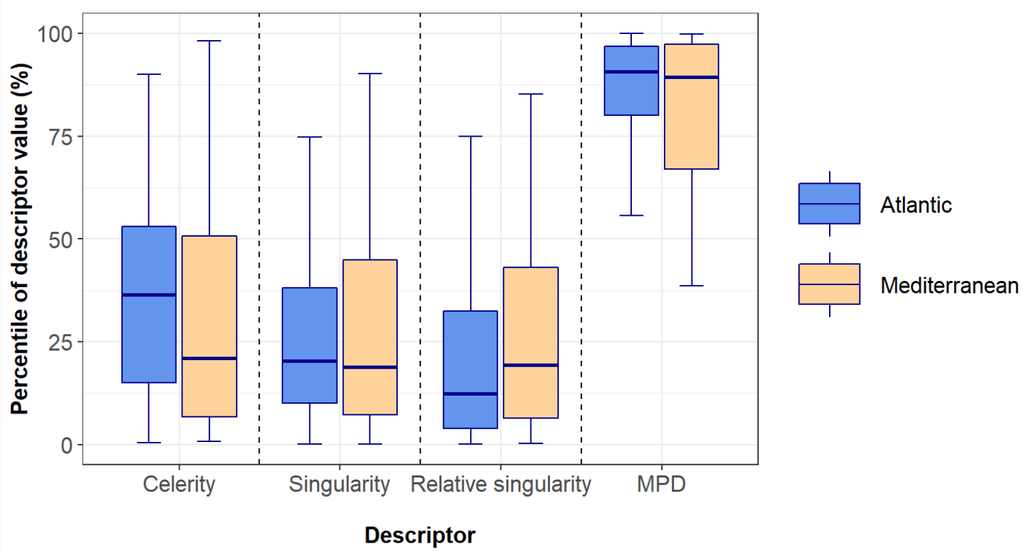
Scatterplot of every 3-day sequence of the period 1950–2017 for MPD against either the celerity (a,b,c), the singularity (d,e,f) or the relative singularity (g,h,i), all being expressed in percentiles. The points are coloured with respect to the density of points in the scatterplot. Densities are either computed on every 3-day sequences (a,d,g), on 3-day sequences belonging to the Atlantic influence (b,e,h), or on 3-day sequences belonging to the Mediterranean influence (c,f,i).

Characterizing Atlantic and Mediterranean circulations driving extreme 3-day precipitation in the Northern French Alps



Same as the previous figure, with the white squares representing EPS

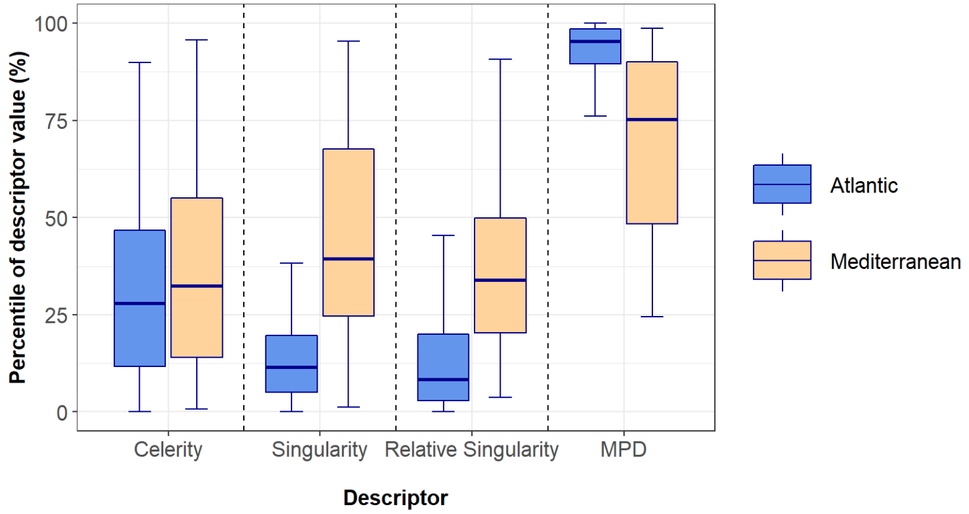
Percentile of descriptors value of EPS associated with Atlantic circulations (142 EPS) and Mediterranean circulations (49 EPS). Percentiles in (a and b) are computed with respect to the 3-day sequences associated to the given atmospheric influence



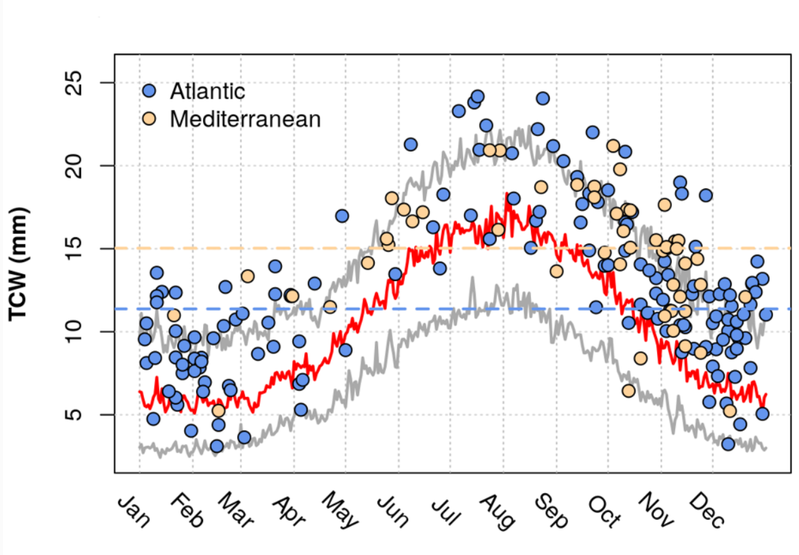
Atlantic/Mediterranean circulations driving EPS in the Northern French Alps are the Altantic/Mediterranean circulations featuring:

- **The strongest centres of action** (MPD);
- **The most reproducible flow directions** (singularity and relative singularity);
- **Quite stationary flow directions** (celerity).

Characterizing Atlantic and Mediterranean circulations driving extreme 3-day precipitation in the Northern French Alps



Same as the previous figure, with percentiles computed with respect to all 3-day sequences over the period 1950–2017



Total Column Water over the Northern French Alps (region represented in red in figure of slide 2) during EPS and seasonality

In comparison to the whole climatology:

- Atlantic EPS feature **extreme large-scale circulation characteristics;**
- Mediterranean EPS feature not as extreme characteristics. The weaker centers of action (MPD) and flow direction stationarity (celerity) reflect **a weaker air advection over a given region.**

Mediterranean circulations driving EPS mostly occur in **autumn** and feature **a larger air humidity** in comparison to Atlantic circulations driving EPS in winter.

⇒ **This suggests an important role played by the atmospheric humidity in producing EPS under Mediterranean circulations**

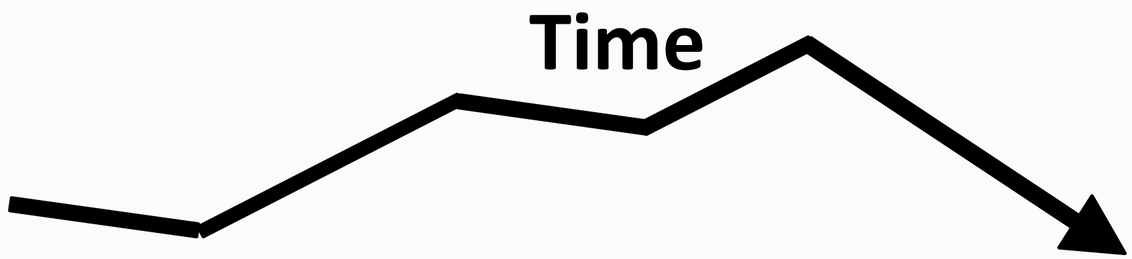
Conclusions

- Atlantic circulations driving EPS in both the Isère and the Drac River catchments are the Atlantic circulations **featuring among the most stationary and reproducible flow directions with among the most pronounced centers of action, corresponding to the strongest and stationary westerlies over 3 days.**

- Mediterranean circulations driving EPS mainly in the Drac River catchment also feature among **the most stationary and reproducible flow directions with among the most pronounced centers of action compared to the other Mediterranean circulations.**

- Mediterranean circulations driving EPS feature a broader spectrum of characteristics that are **not so extreme in comparison to the whole climatology.** They mainly occur in autumn and are associated with **large atmospheric humidity, pointing out a more balanced contribution between specific large-scale circulation and atmospheric humidity** brought from the warm Mediterranean Sea.

This view opens the door to future studies on **the occurrence of such 'critical' LSC characteristics in a climate change context**—whether they will become more or less frequent—an interesting perspective for climate change studies.



References

- ***Blanc, A., Blanchet, J. and Creutin, J.-D. (2021). Characterizing large-scale circulations driving extreme precipitation in the Northern French Alps, International Journal of Climatology 1-16.***

- *Blanchet, J., Stalla, S., & Creutin, J.-D. (2018). Analogy of multiday sequences of atmospheric circulation favoring large rainfall accumulation over the French Alps. Atmospheric Science Letters, 19 (3), e809.*

- *Blanchet, J., & Creutin, J.-D. (2020). Explaining Rainfall Accumulations over Several Days in the French Alps Using Low-Dimensional Atmospheric Predictors Based on Analogy. Journal of Applied Meteorology and Climatology, 59 (2), 237-250.*

- *Garavaglia, F., Gailhard, J., Paquet, E., Lang, M., Garcon, R., & Bernardara, P. (2010, 06). Introducing a rainfall compound distribution model based on weather patterns sub-sampling. Hydrology and Earth System Sciences, 14.*

- *Gottardi, F., Obled, C., Gailhard, J., & Paquet, E. (2012). Statistical reanalysis of precipitation fields based on ground network data and weather patterns: Application over french mountains. Journal of Hydrology, 432-433 , 154 - 167.*

- *Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horanyi, A., Mun~oz-Sabater, J., Thepaut, J.-N. (2020). The ERA5 global reanalysis. Quarterly Journal of the Royal Meteorological Society, 146 (730), 1999-2049.*

- *Teweles, S., & Wobus, H. B. (1954). Verification of Prognostic Charts. Bulletin of the American Meteorological Society, 35 (10), 455-463.*