Recent Greenland warming in early summer and its link to atmospheric blocking trends in the Northern Atlantic sector

Michele Filippucci (Università di Trento, IUSS Pavia), Simona Bordoni (Università di Trento)

Github repository

1. Introduction:

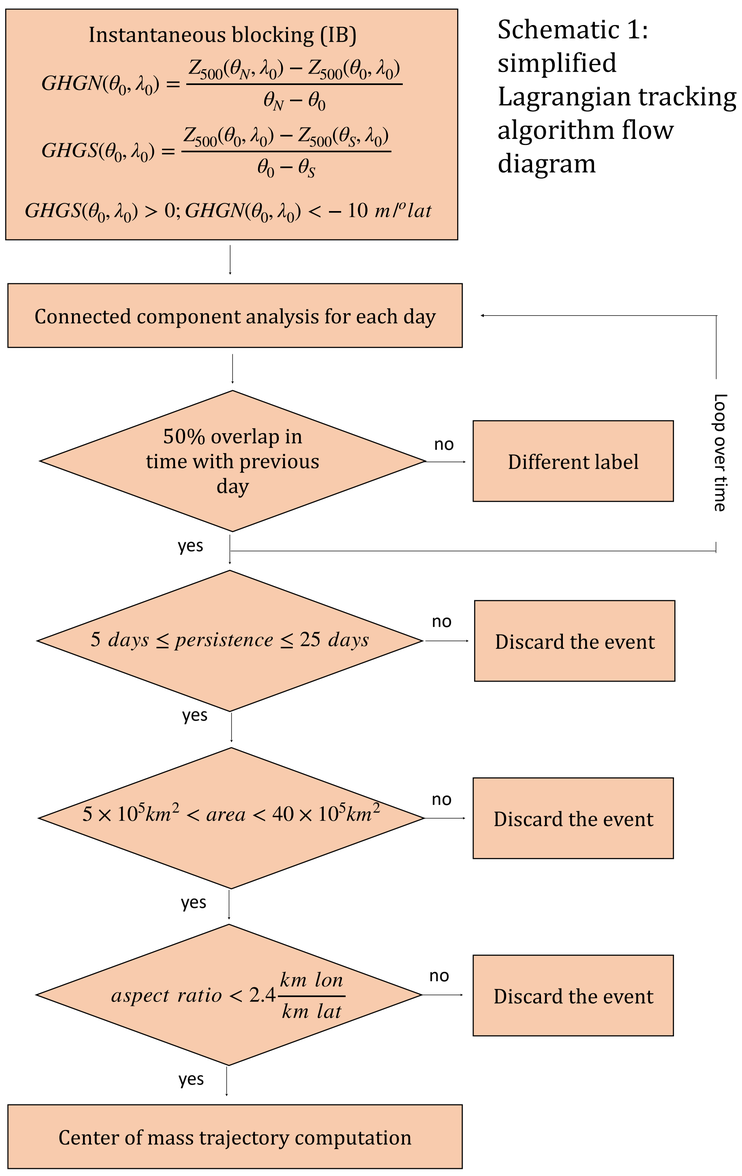
Observations from the last two decades show a **more prominent** negative phase of the **North Atlantic Oscillation (NAO)** in **early summer** (Hanna et al. 2015), causing an accelerated warming and consequent melting of continental Greenland perennial ice. Such a trend can be interpreted in terms of **augmented atmospheric blocking frequency** (Woollings et al. 2008), a synoptic atmospheric pattern that consists in an obstruction of the normal mid-latitudinal westerly weather patterns progression.

A variety of methods for blocking detection exists, and the adoption of one in favour of another determines the kind of blocking detected. Here we introduce a **newly developed detection method** performing a **Lagrangian tracking** of atmospheric blocking events.

Our objective is to isolate the atmospheric blocking events induced by Rossby wave breaking and to understand whether the observed NAO can be explained in terms of their variation.

2. A original Lagrangian tracking algorithm:

In this study we apply this detection method to **60 years** of data from **ERA5 reanalysis (1950-2020).** The developed method exploits a **geopotential height gradient reversal** index for instantaneous blocking detection (Davini et al. 2012) and performs a Lagrangian tracking of blocking events on top of it.



Schematic 1: simplified Lagrangian tracking algorithm flow diagram

3. A blocked-zonal flow decomposition:

We apply a **geopotential height decomposition** aimed at understanding whether the difference between present and historical reanalyses data has to be attributed to blocking. One can write:

$$z-\hat{z}=[fz_b+(1-f)z_z]-[\hat{f}\hat{z}_b+(1-\hat{f})\hat{z}_z]$$

where z is the climatological geopotential height, f is the blocking frequency over a chosen region, and b and z refer to the average over ”blocked” and “zonal” days, respectively, over the chosen area. The hat symbol denotes fields from the present period (1990-2020), whereas symbols without the hat denote fields from historical period (1960-1990). We obtain:

$$z-\hat{z}=(f-\hat{f})(z_b-z_z)+\hat{f}[(z_b-\hat{z}_b)-(z_z-\hat{z}_z)]+z_z-\hat{z}_z$$

where the **geopotential height anomaly** is partitioned into three contributions: **frequency anomaly**, due to differences in blocking frequency; **blocking pattern anomaly**, arising from differences in blocking pattern in the two model versions; **mean state anomaly**, due to differences in the mean state during non-blocked days.

4. What is the effect of the Lagrangian tracking algorithm thresholds?

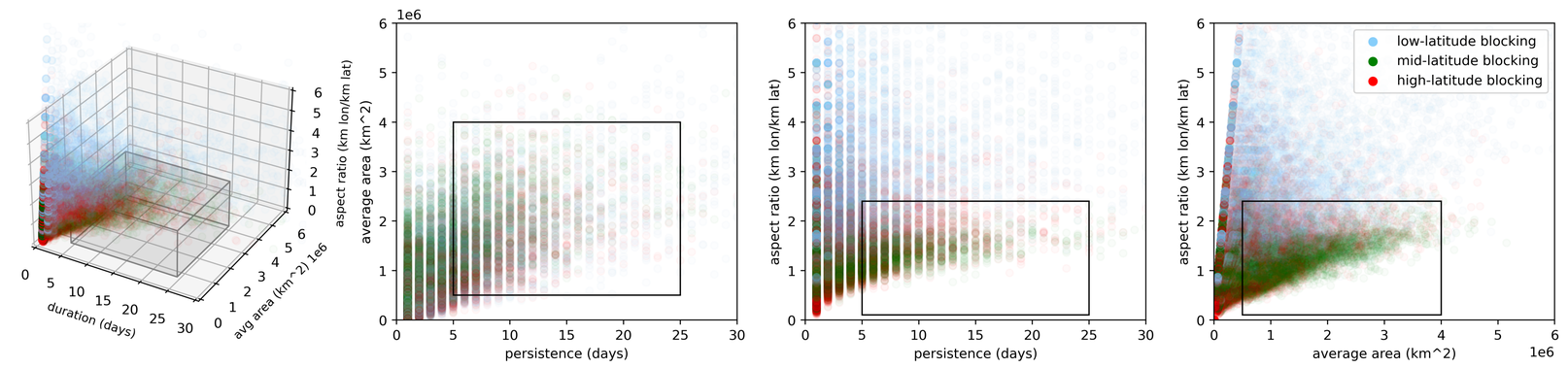


Figure 1: **Atmospheric blocking characteristics** scatter plot. Quantities are indicated on the axes. The cube and the squares indicate the selected events following the filters described in section 2. Colors refer to the center of mass latitudinal position: low latitude: θ_{CM} < 45°N (blue), middle latitude 45°N<θ_{CM}<65°N (green), high latitude: 65°N<θ_{CM} (red)

5. Climatology and composite of the filtered atmospheric blocking events.

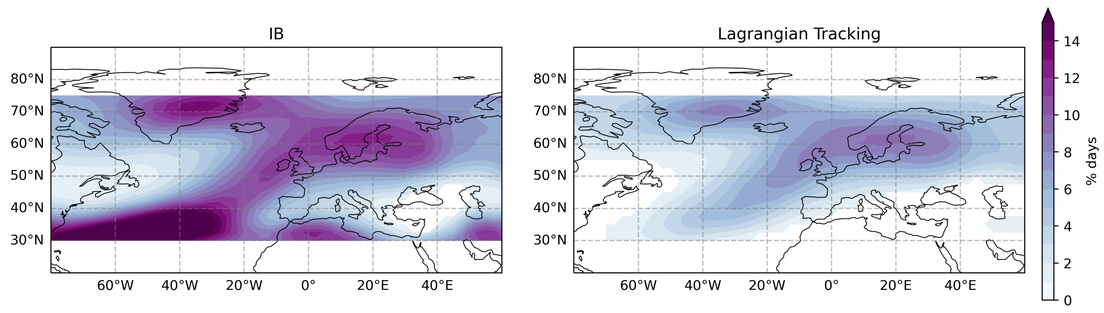
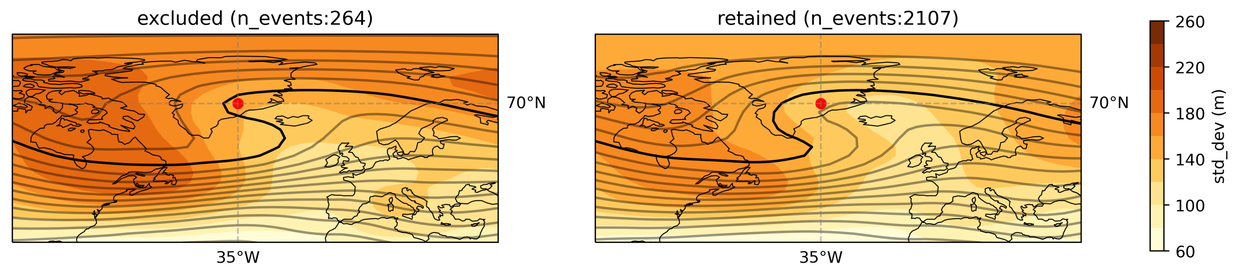


Figure 2: **Atmospheric blocking climatology. IB**: atmospheric blocking frequency obtained through a simple instantaneous blocking definition. **Lagrangian Tracking**: blocking frequency obtained using the algorithm and filtering.

Figure 3: Geopotential height composite of Greenland atmospheric blocking. **Retained**: events that satisfy all the conditions, **Excluded**: events rejected following the **aspect ratio criteria**.



6. Greenland atmospheric blocking evolving characteristics.

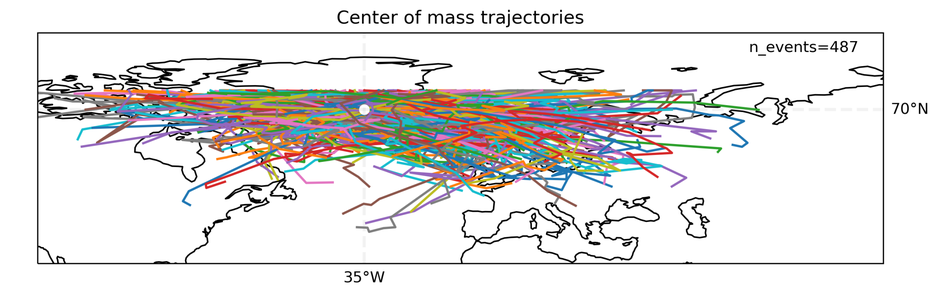


Figure 4: **Center of mass trajectories** of the atmospheric blocking events passing by the coordinates **(35°W,70°N).** Events must spend at least five days over the indicated point and they must cover a distance smaller than 10.000 km during their life cycle.

Figure 5: **Characteristics of atmospheric blocking events** whose trajectories are plotted in Figure 4. The red squares indicate trends that exceed 2σ.

7. NAO- pattern and atmospheric blocking frequency.

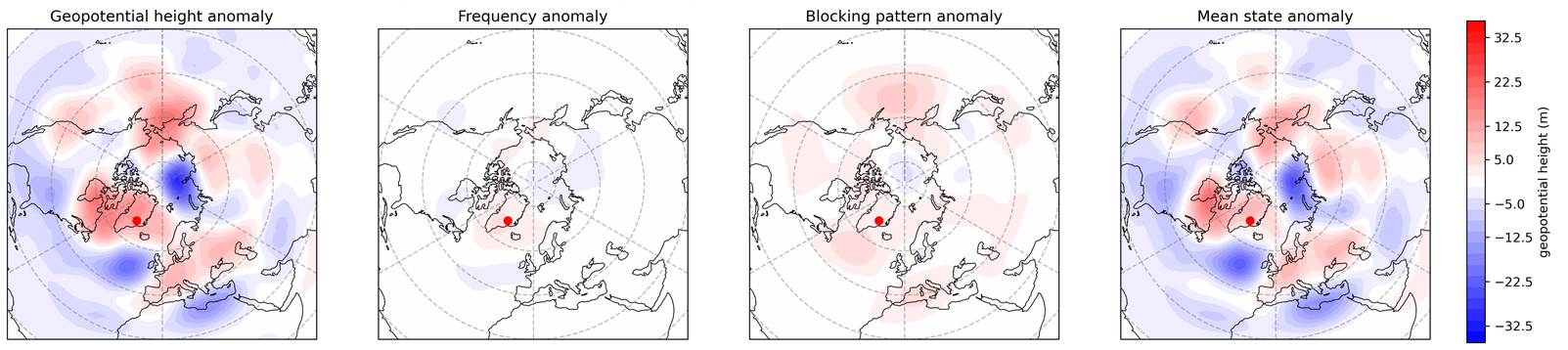


Figure 6: **Decomposition** of the detrended geopotential height field at 500hPa difference between **present** period (1989-2019) and **historical** period (1959-1989). The decomposition is described in Section 3. All shadings are significant at 95% confidence interval. Uncertainties have been assessed through a bootstrap test.

8. Take home messages and open questions:

- The **number of Greenland atmospheric blocking events** is **increasing in summer.**
- Changes in the **meridional displacement** are **small but significant.**
- The more prominent **NAO- negative phase** in summer in recent decades is **associated with both an increased blocking frequency and a mean circulation change.**
- The **blocking pattern anomaly change** suggests a **link with Arctic Amplification**.

Contact: Email: michele.filippucci@unitn.it LinkedIn: michele-filippucci

IUSS Scuola Universitaria Superiore Pavia