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Air-sea interactions and diabatic processes in the Gulf Stream region and their role in the life-cycle of a blocking anticyclone: a case study of European Blocking in Feb 2019

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February 2019 Heatwave

An episode of European blocking that took place in the period between 20 and 27 of February 2019 was accompanied by a record-breaking warm spell bringing temperatures above 20°C to the United Kingdom, Netherlands, and Northern France.

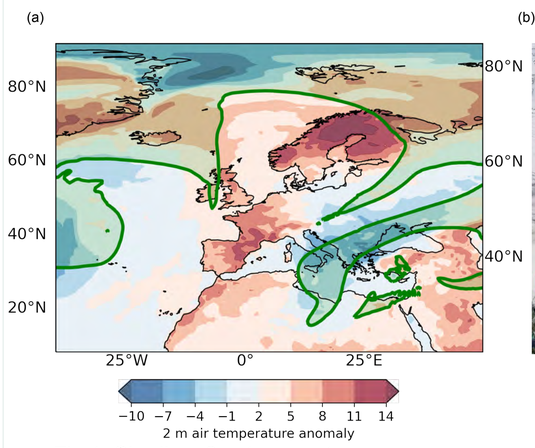


Fig.1. Shading: 2 m temperature anomaly on 23.02.2019, green contours: 2 PVU line, areas with PV>2 shaded in light green.

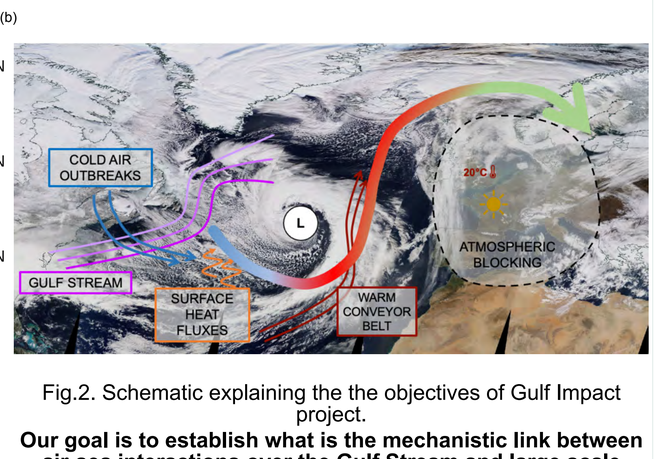


Fig.2. Schematic explaining the the objectives of Gulf Impact project.

Our goal is to establish what is the mechanistic link between air-sea interactions over the Gulf Stream and large scale dynamics - in particular the formation of atmospheric blocks over Europe.

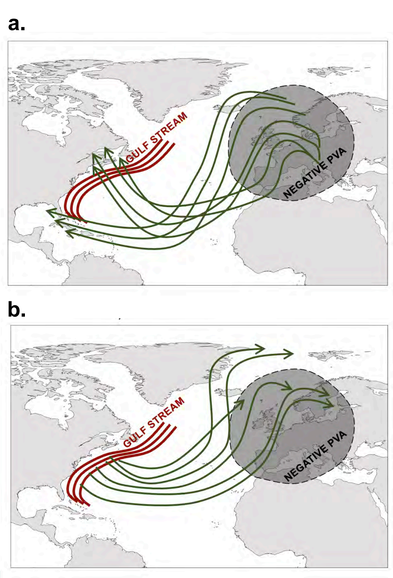
Methods

Lagrangian trajectories computed using LAGRANTO (Sprenger & Wernli, 2015) and ECMWF ERA5 (Hersbach et al., 2020) reanalysis:

a. Trajectories are run 10 day backward with an interval of 3 h from the negative potential vorticity anomaly objects (NPVA, Schwierz et al. 2004) forming the Feb. 2019 European Blocking for the period of 18.02.2019 09:00 to 28.02.2019 12:00.

b. Trajectories are run 10 day forward with an interval of 3 h from the Gulf Stream (GS) SST front for the whole month of Feb 2019.

A selection criterium of an ascent of 500 hPa anytime throughout the trajectories is applied to both datasets.
In the post processing backward trajectories that passed over GS SST front prior to ascending into the blocking are selected.



Identification of different airstreams

Trajectories characterized by different processes are selected from the initial trajectory dataset based on the following criteria:

❖ **WCB**- warm conveyor belt (Madonna et.al.2014), ascent of 600 hPa within 48h

❖ **Dry Intrusion** (Raveh-Rubin, 2017), descent of 400 hPa within 48h

❖ **CAO**- cold air outbreak (Papritz and Spengler, 2016), $\theta_{SST}-\theta>2$

❖ **DH**- diabatic heating (Pfahl et.al., 2015), $\Delta\theta>2$

Rapidly Intensifying Cyclones

The formation of the block is accompanied by several (two shown), rapidly intensifying cyclones originating in the Gulf Stream region and traversing the North Atlantic.

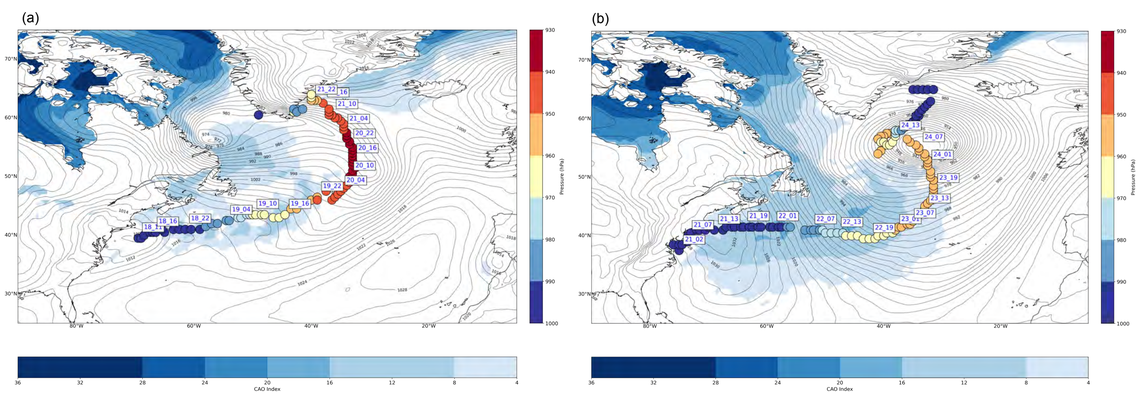
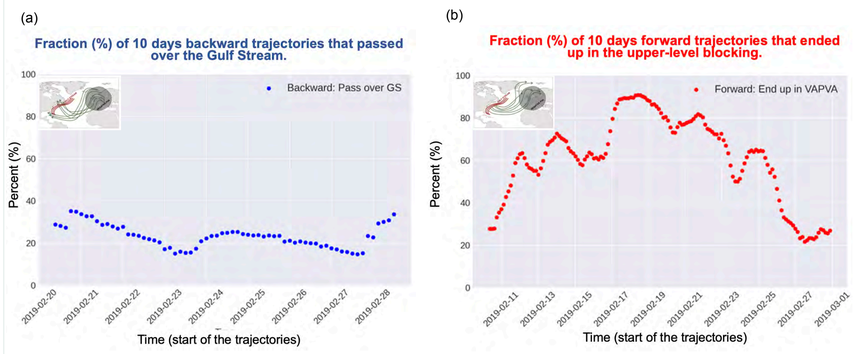


Fig. 3. Pressure coloured dots show the track of a cyclone formed on (a) 18.02.2019, 11:00 and (b) 21.02.2019 02:00, coloured contours denote cold air outbreak and black contours mean sea level pressure on (a) 18.02.2019, 12:00 and (b) 21.02.2019 00:00.

Trajectories Characteristics



❖ On average 25% of trajectories started from the NPVA objects interact with the Gulf Stream and 60% of those started from the Gulf Stream region ascend into the blocking region.

Fig.4. Fraction (%) of trajectories (a) that started from NPVA objects and passed over GS and (b) started from the GS and ascended into NPVA .

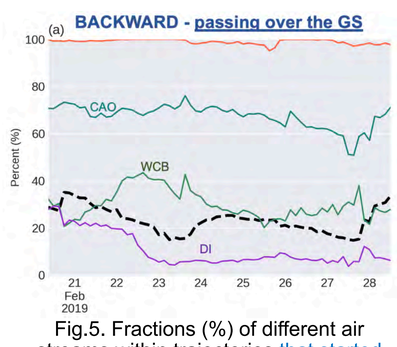


Fig.5. Fractions (%) of different air streams within trajectories that started from NPVA objects and passed over GS.

❖ All of the backward trajectories started from the block and passing over the Gulf Stream in the lower troposphere were diabatically heated.

❖ Approximately 75% of them have passed through the region affected by Cold Air Outbreak.

❖ On average 24% of the trajectories are identified as Warm Conveyor Belt, thus ascend rapidly into the upper troposphere.

❖ Those results suggest that there is a potential connection between CAOs, diabatic heating and the large scale dynamics associated with the formation of the block in February 2019.

Sources of moisture for trajectories

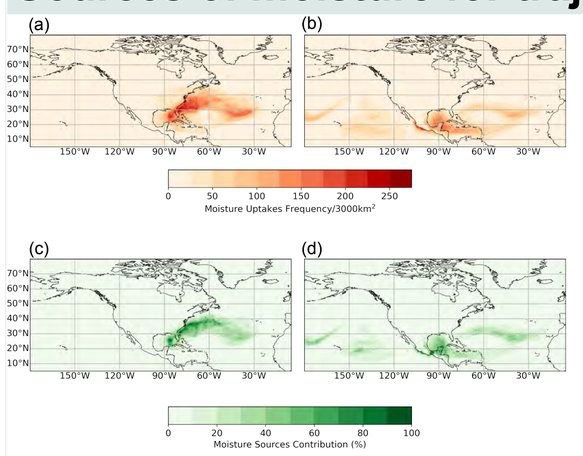


Fig.6. Sources of moisture for the trajectories that interacted with the Gulf Stream (left column) and those that didn't (right column). (c) The frequency of moisture uptakes. (d) Moisture sources' contributions (%).

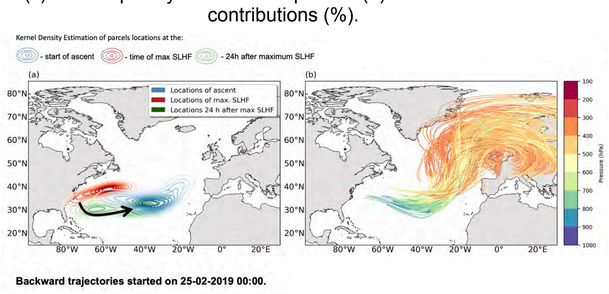


Fig. 7. Trajectories locations at maximum surface latent heat flux (red contours), 24 after having maximum SLHF (green contours) and when they start their ascent (blue contours).

❖ We use the moisture diagnostic of Sodemann, 2013 to identify moisture sources for the **ascent** of all backward trajectories started from the NPVA objects.

❖ Passage of rapidly intensifying cyclones drives the cold, continental air across the SST front creating conditions for large exchange of moisture between ocean and the atmosphere.

❖ Trajectories that interact with the Gulf Stream and later ascent into the block pick up moisture along, and to the south of the Gulf Stream.

❖ Those air masses that do not interact with the Gulf Stream gain moisture in different regions. We also determined that their ascent takes place over the Gulf of Mexico, form where they are advected in the upper troposphere toward the block.

❖ Trajectories that passed through the atmospheric boundary layers over the Gulf Stream gain moisture behind the cold front of one cyclone passing through western North Atlantic and are lifted into the upper troposphere by an ascending air stream of consecutive cyclones - they participate in the co called 'Hand Over' mechanism (Papritz,2020)

Summary and outlook

❖ **Presented results show that:**
- ❖ the GS SST front region provides heat and moisture for the air masses that later ascent into the block and that this contribution might be essential for the development of European Blocking.

❖ **Outlook:**
- ❖ An APE budget framework (Novak and Tailleux, 2018) will be applied to study the local energetics of the cyclones associated with the blocking.
- ❖ Similar setup of trajectories is going to be calculated for the whole ERA5 period (1979-2021).

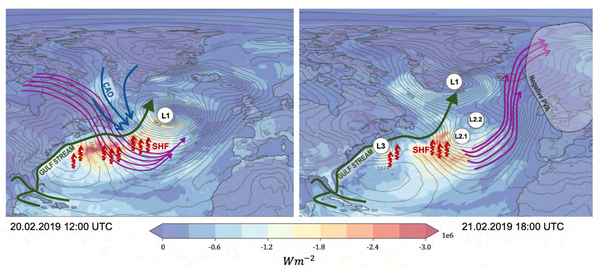


Fig. 8. Schematic explaining the 'hand over' mechanism. **L** refers to the center of different cyclones, purple arrows indicate the movement of air, green line- the Gulf Stream, red arrows portray the transfer of heat from the ocean to the atmosphere. Shading: surface latent heat flux, accumulated over 3 hours.

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