Heavy Alpine snowfall in January 2019 connected to atmospheric blocking

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Introduction

European Alps are exposed to the mid-latitude winter weather dominated by the nonlinear jet stream dynamics. In the euro-Atlantic region, jet stream configuration and atmospheric blocking modulate tropospheric moisture transport. Previous studies have manifested that winter tropospheric and stratospheric circulation anomalies are dynamically coupled (Kidston et al. 2015; Baldwin and Dunkerton 2001).
The synoptic situation of January 2019 comprised sudden stratospheric warming and the atmospheric blocking over the North Atlantic that led to significant snow amounts in the Northern Alps. Here we investigate atmospheric conditions that prevailed in 2018/19 winter. The analysis is based on ERA-5 reanalysis data (Hersbach, H. and D. Dee 2016).

1. Evolution of snowfall and moisture transport

From 30 December 2018 to 15 January 2019, intense snowfalls affected the entire Austrian side of the northern Alps. The snowfalls were caused by individual weather situations created by several front systems transported from the north. In some regions, snowfall was defined as 100-years event, meaning that the event statistically occur every 100 years (Radlherr et al. 2020).

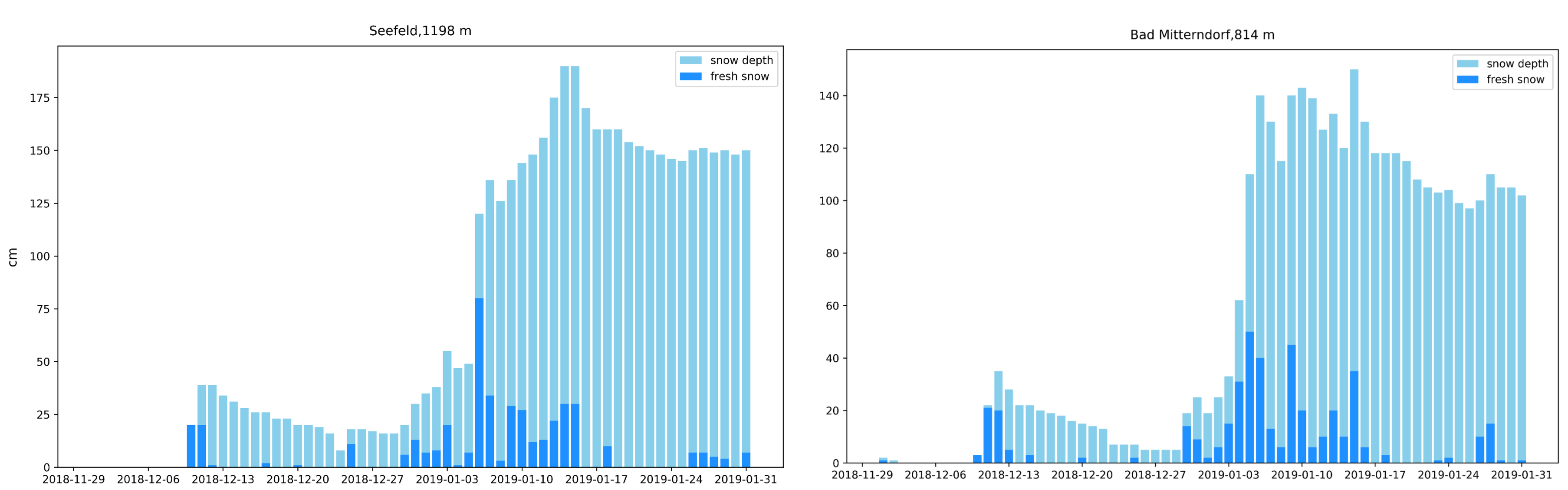

Figure 1. Development of daily fresh snow (bright blue) and snow depths (light blue) at the stations Seefeld, Bad Mitterndorf for December 2018 to January 2019. Data are provided by Central Institute for Meteorology and Geodynamics (Schöner et al. 2019)

Here, we display vertically integrated water vapour flux for 2 January 2019 (Figure 2). Apparently, moisture is carried along the meridionally elongated trajectory from the North Atlantic through Northern Europe to Central Europe, reaching the Northern Alps.

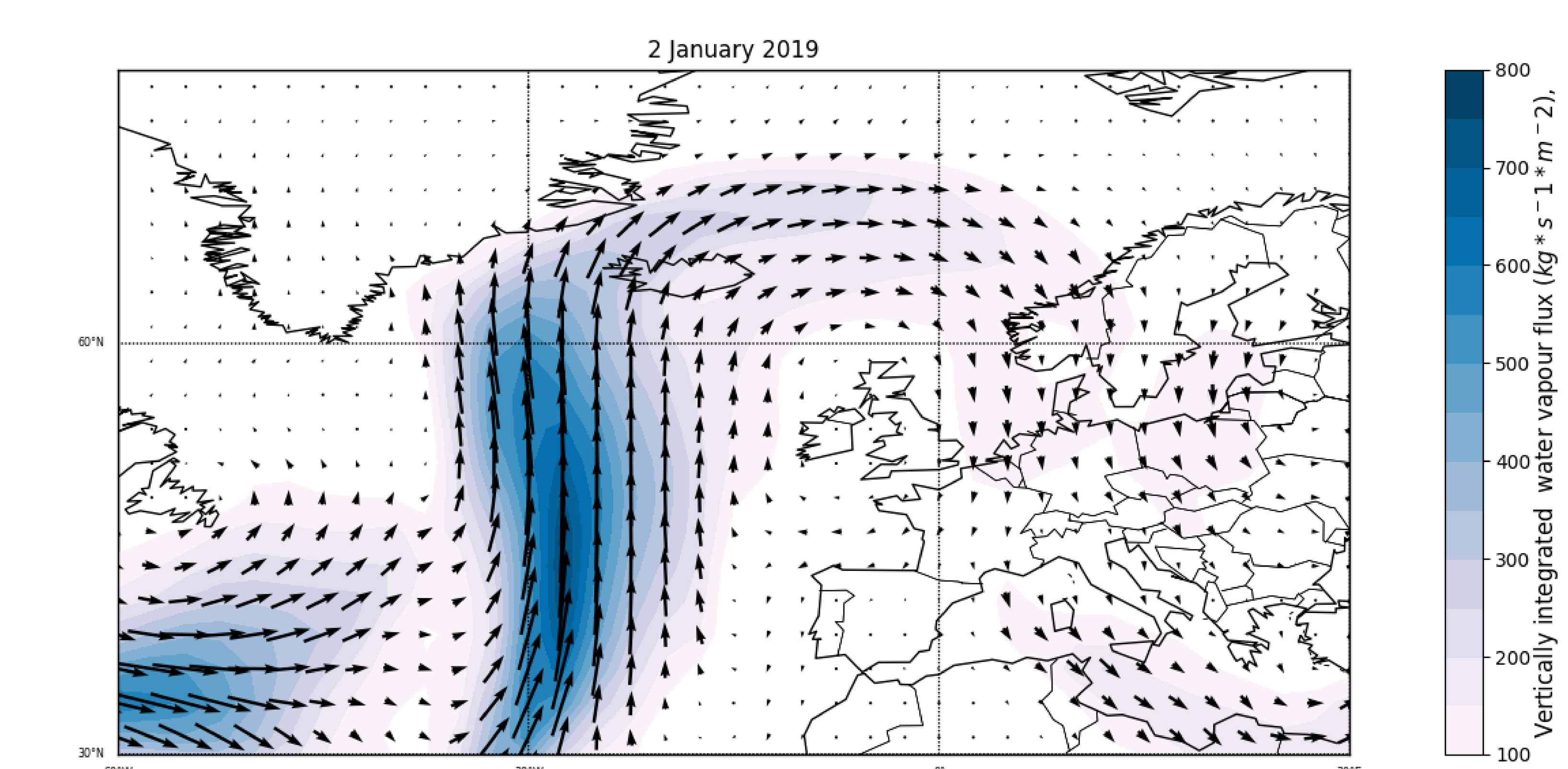

Figure 2. Vertically integrated water vapour flux for 2 January 2019 according to ERA-5 reanalysis. Shading corresponds to the flux magnitude, vector field to the flux direction.

2. North-Atlantic blocking

Strong positive high-pressure anomaly is located over the North Atlantic ocean centering at 25°E and 60°N (Figure 3). The near-surface synoptic pattern is aligned with 500 hPa configuration, which resembles near-barotropic structure (Figure 3). Blocked longitudinal distribution is shown as a Hovmöller plot in Figure 4 .
Vertical cross-section of geopotential height anomalies over the location of blocking between 50°N - 70°N and 30°E – 30°W (Figure 5) reveals that there was a coupling between the stratosphere and lower troposphere from the end of December 2018 to 1 January.

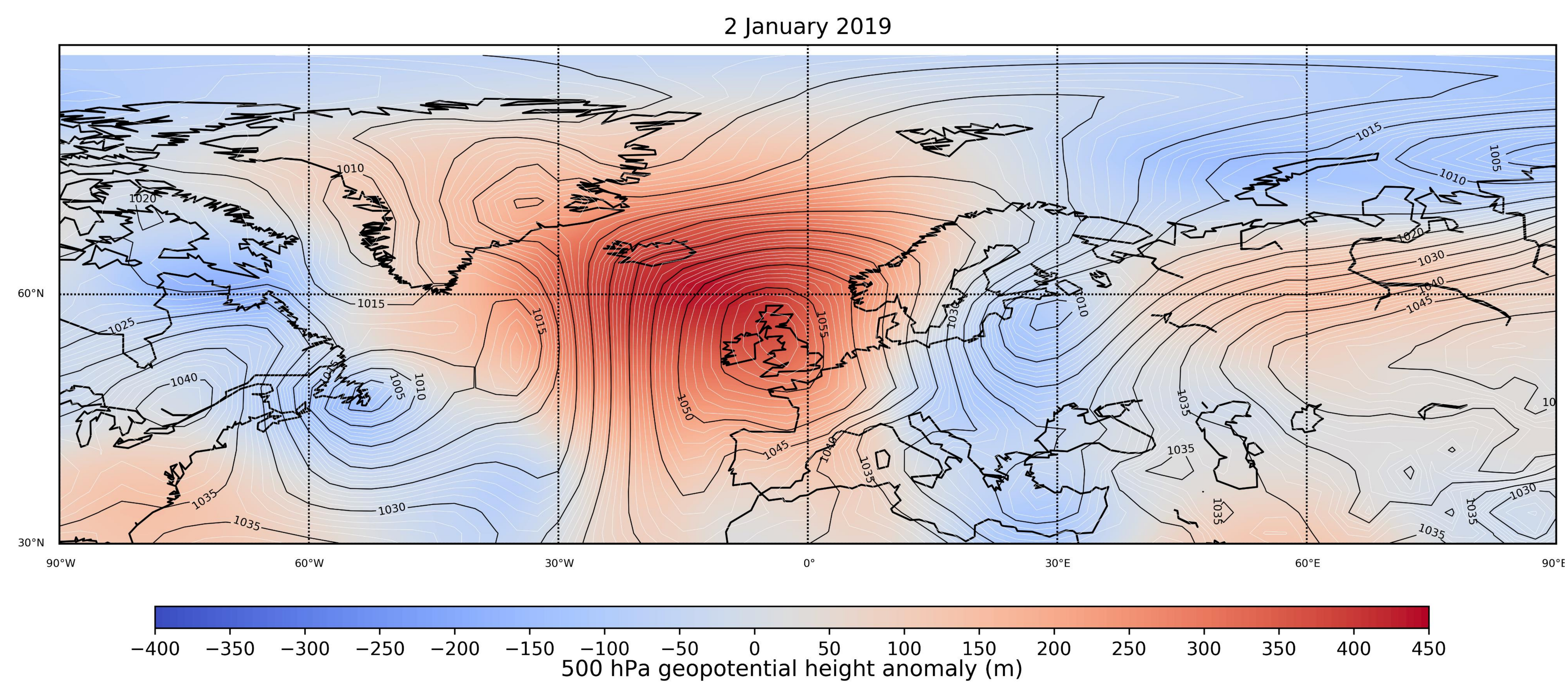

Figure 3. 500 hPa geopotential height anomalies and surface pressure (mean sea-level pressure) for 2 January 2019. Black contours correspond to the MSLP field, shading to 500 hPa field.

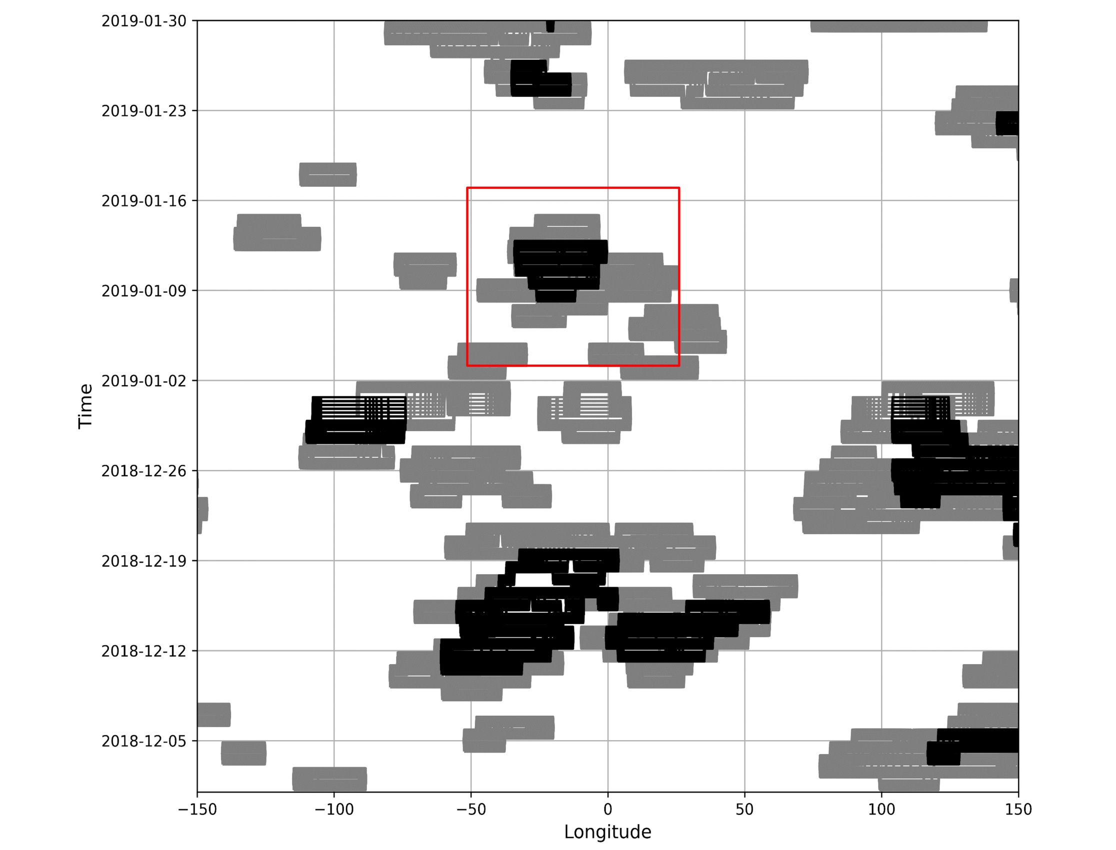

Figure 4. Hovmöller diagram of the blocking indices (Brunner et al. 2016; Tibaldi and Molteni 1990). Grey contours correspond to Instantaneous Blocking (applied GPH gradients criteria) black contours to Blocking (applied persistence criteria).

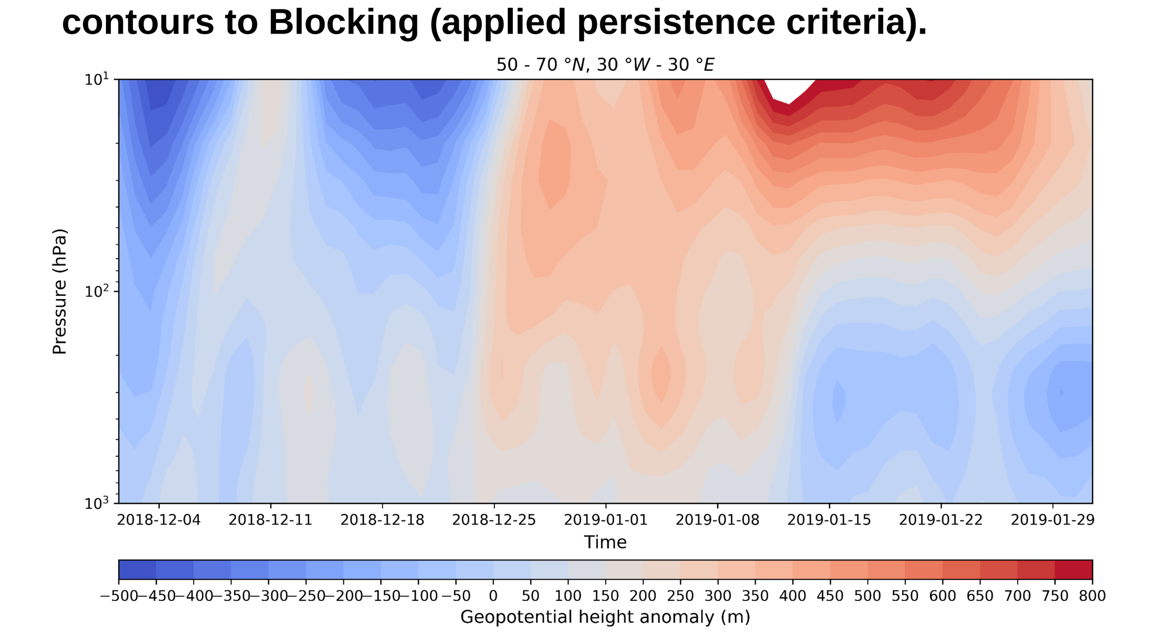

Figure 5. Vertical cross-section of 50°N - 70°N and 30°W - 30°E average geopotential height anomalies for December 2018 to January 2019.

3. Sudden Stratospheric Warming 2019

A major sudden stratospheric warming (SSW) is observed in January 2019. Positive temperature and geopotential anomalies descending from 10 hPa to 200 hPa are observed throughout the atmospheric column from the end of December 2018 to the end of January 2019 (Figure 6, a and b). On January 2, the vortex splits in two, with one lobe residing over north-west Atlantic/Canada and another over Northern Europe (Figure 6, c). The two vortices, exhibit a very weak coupling with the low-pressure systems at 500 hPa embedded in the troughs of the North Atlantic omega block shown in Figure 3.

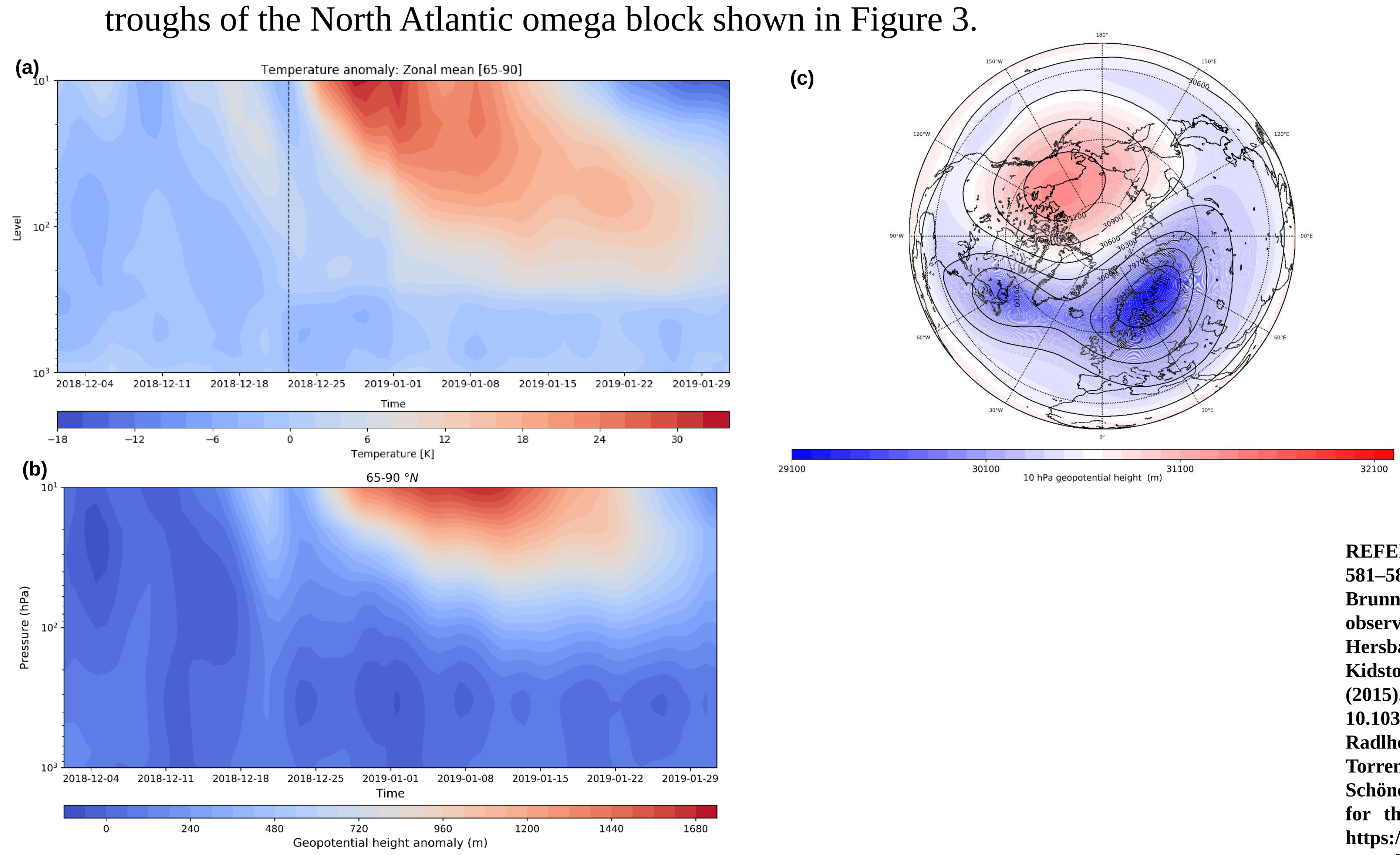

Figure 6. (a,b) Time series of 65°N - 90°N zonal average temperature and geopotential height anomalies. Dashed vertical line indicates peak corresponding of the onset of SSW on 22 December 2018. (c) 10 hPa geopotential height (filled and contoured) , showing vortex split on 2 January 2019.

Discussion

Blocking over the eastern North Atlantic led to the north inflow, which caused a variety of individual meteorological situations in the mountains, leading to series of heavy snowfalls. The extreme amounts of snow set record values in historical snow observations.
The examined co-occurrence of the atmospheric blocking and the SSW in December 2018 – January 2019 does not clearly indicate that one of these phenomena is triggered by another. However, it suggests that the events were connected.
Our study highlights the importance of further investigation of winter blocking events in connection to SSW. To better identify the dynamical connection between blocking, SSW and surface weather, modelling efforts are necessary.

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