Diabatic PV Modification along the Inflow of Atmospheric Blocks

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1 Conclusion

This case study demonstrates the importance of diabatic processes for atmospheric blockings:

- **Ascending/Descending** air masses **reinforce/weaken** the blocking PV anomaly by **accumulating negative/positive PVR** along their pathway, in addition to the advection of low/high PV air masses from low/high altitudes.
- **WCBs** therefore seem to play a **reinforcing** role in the lifecycle of atmospheric blocks.
- **In-cloud** processes are most important for PV **destruction** (convection, condensation, deposition).
- **Above cloud** processes are most important for PV **production** (radiation, turbulence).

2 Motivation

Atmospheric blocks are quasi-stationary high-pressure system, which block and redirect the prevailing westerly flow, potentially causing droughts and heatwaves in summer and cold air outbreaks in winter.

Recent studies[1,2] indicated that diabatic processes play a key role in modifying the air masses that maintain such an atmospheric blocking. **Fig. 1** exemplarily shows a block over Canada in May 2016, which induced severe forest fires. The ascent exhibits a distinct ascending inflow. The detailed effect of diabatic processes and subsequent modification of potential vorticity (PV) along ascending air masses associated with atmospheric blocking however remains unclear. The occurrence of diabatic processes along warm conveyor belts could therefore pose as an important factor for the lifecycle of a blocking.

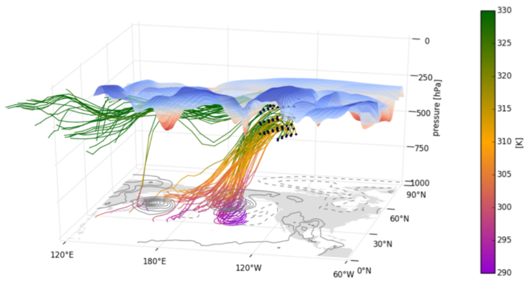

Fig. 1. Ascending inflow of an atmospheric blocking in May 2016, line colors denote potential temperature. Figure from Daniel Steinfeld's dissertation .

3 Methods

Atmospheric blocks were identified by applying an adapted index developed by Schwierz at al. (2004)[3]. The algorithm defines areas as blocks if the mean PV anomaly between 150 - 500hPa exceeds -1.3PVU and the area is spatial and temporal persistent.

We thereby identified a suitable atmospheric block in the Northern Atlantic, which developed around the 10th of January, 2018 and dissolved after 9 days. Its lifespan was characterized by a number of surges from lower levels, one especially intense one around the 16th of January (**Fig. 2**).

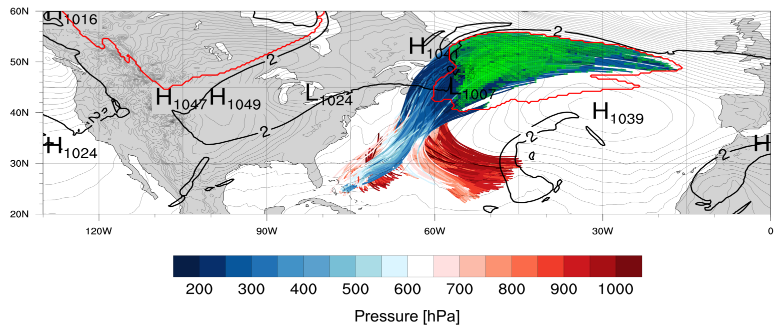

Fig. 2. Trajectories (pressure in color) and end position (green dots) inside the blocking mask at 16 UTC (16th of January, 2018) of strongly ascending air masses (>400hPa 48h^{-1}). Transparency of green dots indicate the number of trajectories at each grid points.

We started 48-hour backward trajectories from each grid point inside the blocking mask between 500hPa and 150hPa at each 6-hourly time step. Along these pathways different temperature, momentum tendencies and their induced PV rates from the IFS were traced, similar to the approach by Joos and Wernli (2012)[4]. These instantaneous PV rates (PVR) were then added up in order to obtain the integrated PVR (IPVR) of each trajectory, as it was done by Attinger et al. (2019)[5].

Thereby, we were able to quantify the PV modifying effect of a wide range of diabatic processes.

4 Data

We used the ERA-Interim reanalysis provided by the European Center for Medium Range Weather Forecast (ECMWF) to identify a suitable case study.

As we were interested in temperature and momentum tendencies caused by a wide range of diabatic processes, a high resolution IFS simulation was calculated for a chosen 7-day period. We thereby analyzed the following temperature/momentum tendencies and their subsequent PV rates:

Radiation:	Long-/shortwave cooling/heating
Turbulence:	Turbulent heating/momentum
Convection:	Convective heating/momentum
Microphysics:	Condensation, cloud/rain evaporation, ice/snow sublimation, ice/snow melting, deposition, freezing, riming, Bergeron-Findeisen process

5 Results and discussion

The inflow of the chosen case study originates from a wide range of height levels over the entire lifespan. The starting level not only affects the transport of low-/high-PV air masses from high/low altitudes, but also the IPVR along the pathway of each trajectory. The PV anomaly over the entire blocking mask thus varies, depending on the composition of the inflow (respective ascent rate), as it can be seen in **Fig. 3**. A large number of ascending air masses coincides with a mean decrease of the blocking PV anomaly, vice versa for descending airmasses.

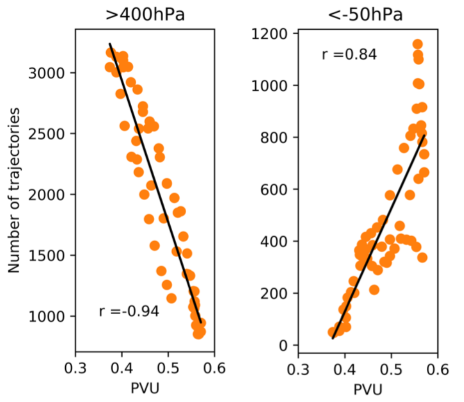

Fig. 3. Correlation between number of ascending (>400hPa 48h^{-1}) or descending (<-50hPa/48h) trajectories and mean PV anomaly over blocking mask over the entire lifecycle.

The contribution of a wide range of diabatic processes to the modification of PV along the inflow is shown in **Fig. 4**. We averaged the IPVR due to each diabatic process over the entire inflow at each timestep. On average, above cloud processes, such as radiation and turbulence produce PV, thereby decreasing the negative PV anomaly of the block. Microphysics and convection on the other hand tend to destroy PV and enhance the PV anomaly of the block.

Thus, surges of ascending air masses shift the total IPVR (black line) of the inflow towards negative values. This process became most visible around the 16th of January, when a large number of trajectories ascended strongly towards the blocking mask.

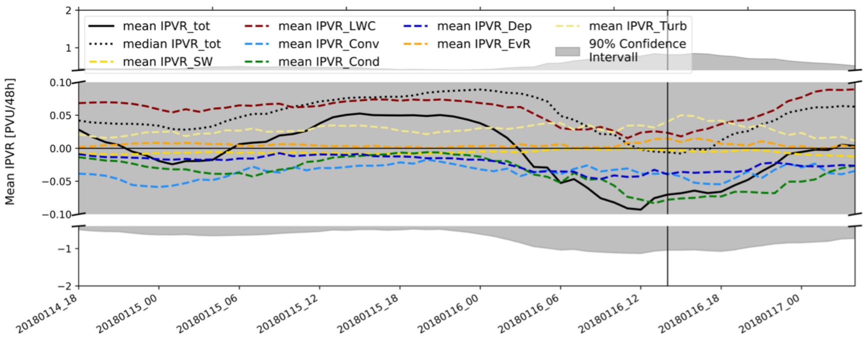

Fig. 4. Mean IPVR at each timestep due to different diabatic processes along the inflow of a blocking case study in January 2018, shown for a section of the entire life cycle.

6 References

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5. **Attinger, Roman, et al.** "Quantifying the role of individual diabatic processes for the formation of PV anomalies in a North Pacific cyclone." Quarterly Journal of the Royal Meteorological Society 145.723 (2019): 2454-2476.