The sensitivity of atmospheric blocking to changes in upstream latent heating

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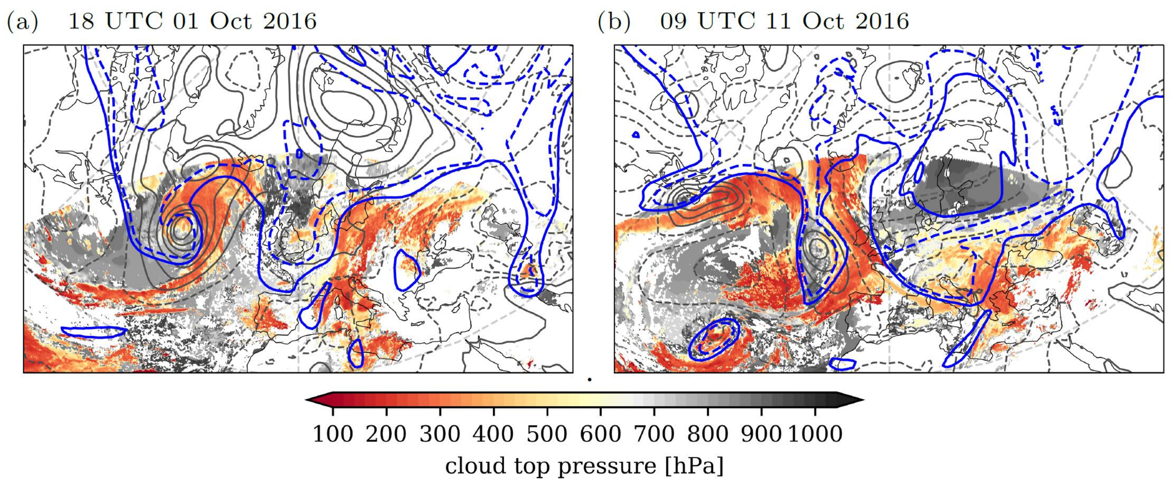
Motivation

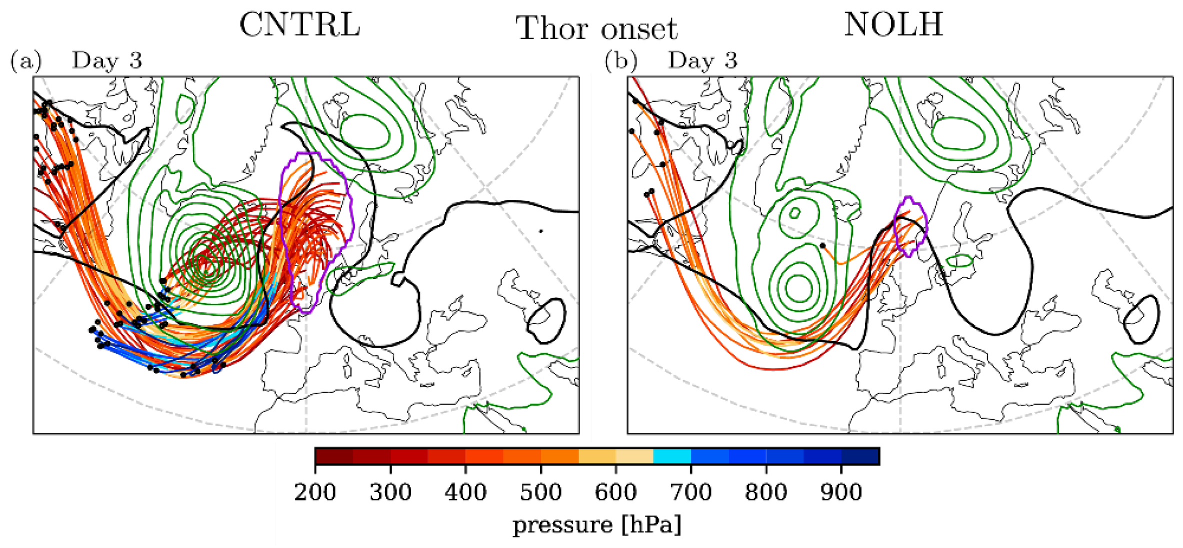
- Atmospheric blocking is a key component of extratropical weather variability and can contribute to various types of extreme weather events.
- Recent diagnostic studies based on trajectory calculations have pointed to an important role of latent heating during cloud formation in warm conveyor belts for the dynamics of blocking anticyclones [1,2].
- Objective of this study: Explicitly study the causal relationship between latent heating and blocking based on model experiments.

Approach

- Case studies of 5 blocking events with the global ECMWF IFS model.
- Sensitivity experiments in which latent heating in clouds is artificially eliminated (denoted as NOLH) or modified in a region upstream of the blocking anticyclone.



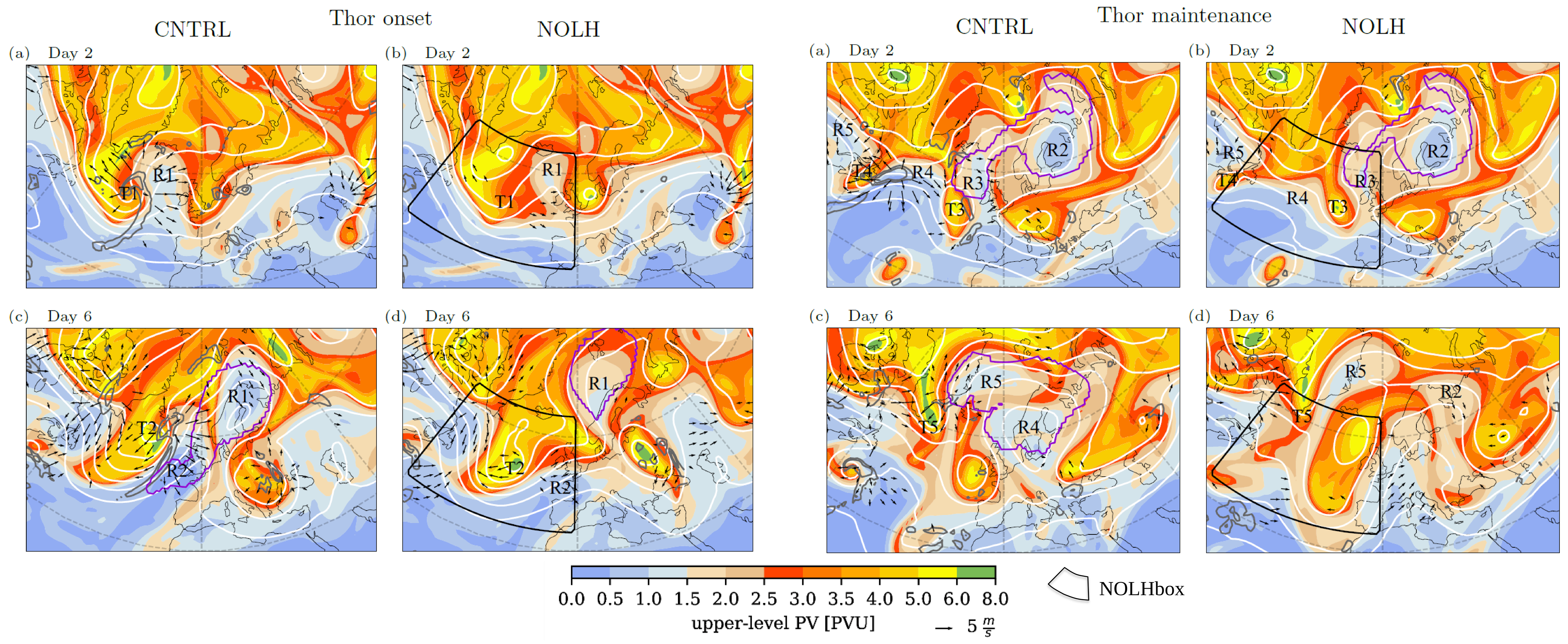
Block "Thor". *SLP (gray contours) and upper-level PV (blue contours, 2 (solid) and 3 (dashed) pvu) from the reference simulation. Shading shows cloud top pressure from EUMETSAT MSG-SEVIRI satellite data.*



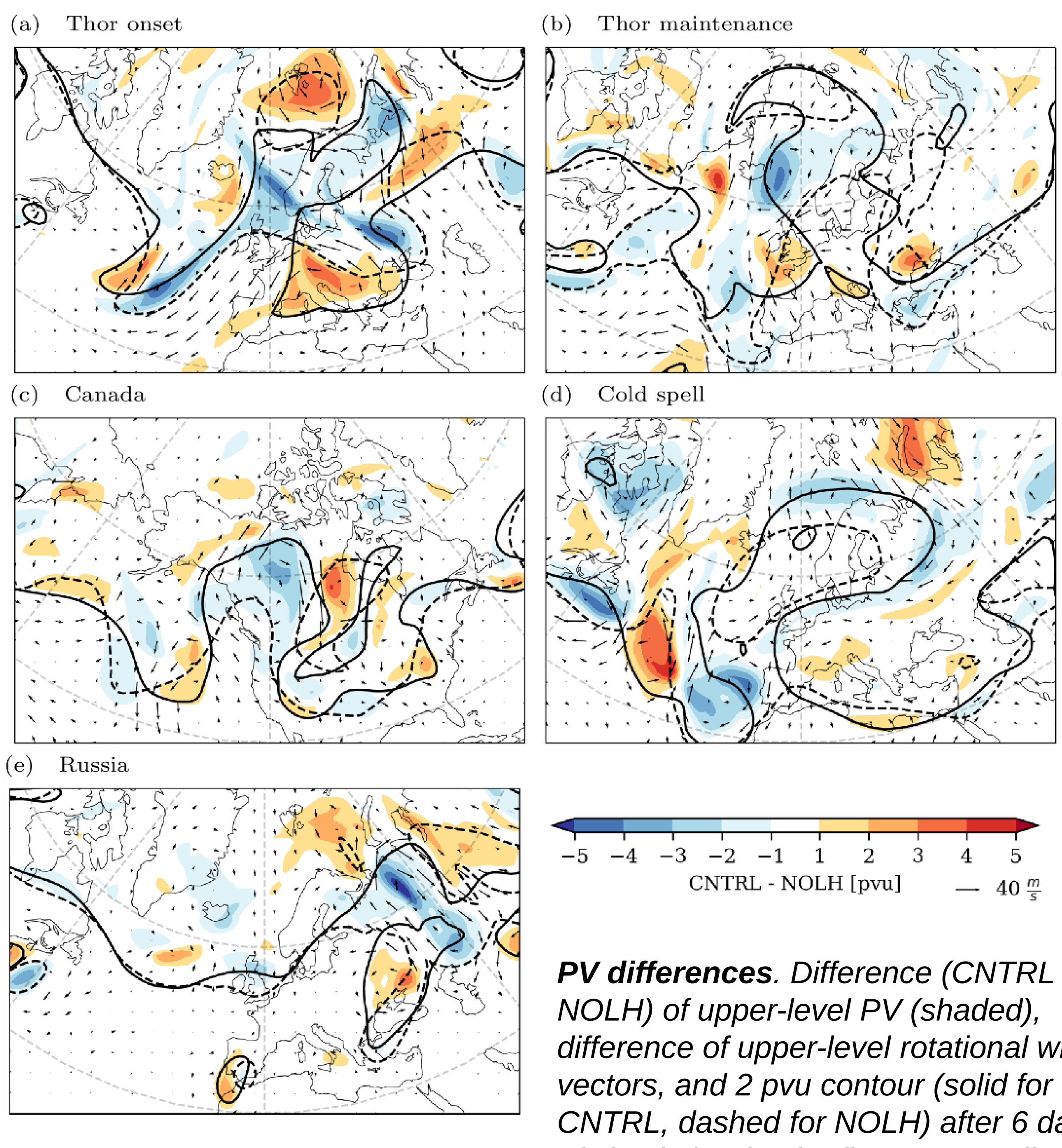
Sensitivity simulation*. Upper-level 2 pvu contour (black), sea level pressure (green) and blocking region (magenta) from (a) CNTRL and (b) NOLH simulation for case "Thor" at 00 UTC 4 October 2016. Colored lines show 3-day backward trajectories initialized in the upper-level block.*

Case study "Thor"

Synoptic evolution*. Upper-level PV (shading), upper-level divergent wind (black vectors), geopotential height at 500 hPa (white contours), latent heating in clouds (1 and 3 K (3 h)$^{-1}$ in gray contours, vertically integrated between 900 and 500 hPa), and blocking region (magenta contour) in reference (CNTRL) and NOLH simulations at (a,b) 00 UTC 2 October 2016, (c,d) 15 UTC 5 October 2016, (e,f) 9 UTC 11 October 2016 and (g,h) 9 UTC 16 October 2016. Black box indicates region where LH is turned off, which extend vertically between 900 and 500 hPa.*

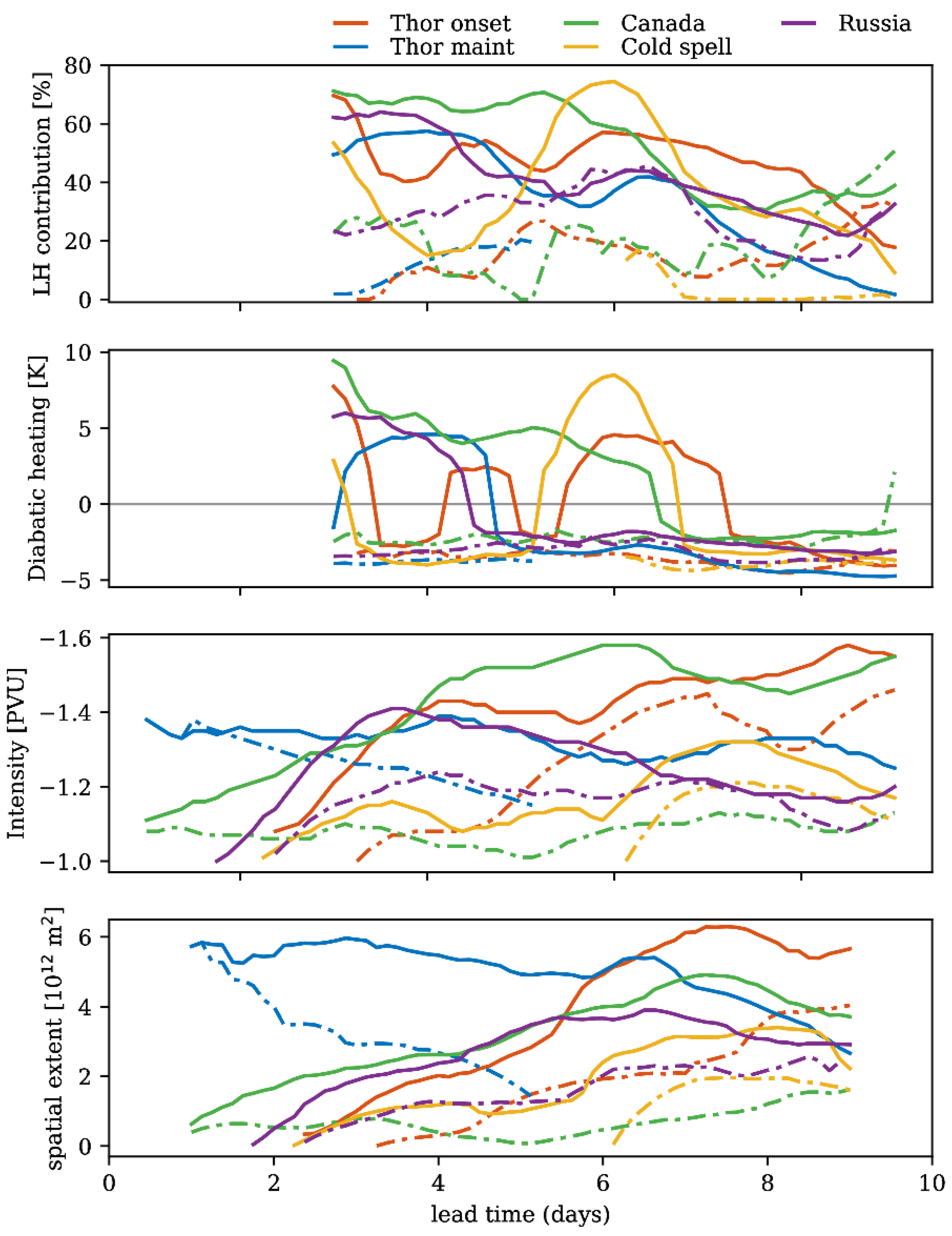


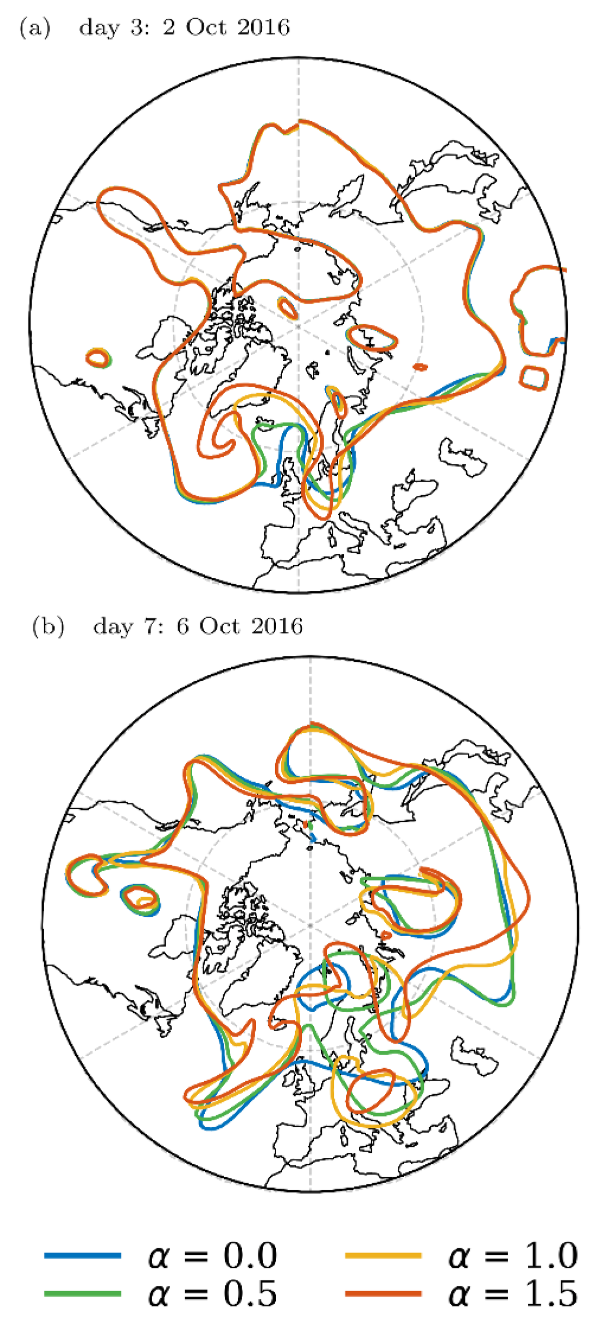
Effect of latent heating



PV differences*. Difference (CNTRL - NOLH) of upper-level PV (shaded), difference of upper-level rotational wind vectors, and 2 pvu contour (solid for CNTRL, dashed for NOLH) after 6 days of simulation for the five case studies.*

Differences in blocking characteristics*. (a) Percentage of backward trajectories with maximum diabatic heating of more than 2 K in 3 days, (b) diabatic heating (K), (c) blocking intensity (PV anomaly), and (d) spatial extent as a function of lead time. Solid lines for CNTRL simulations, dashed lines for NOLH simulations.*





Influence of modified heating*. 2 pvu contour for case "Thor" on (a) 2 October 2016 (day 3) and (b) 6 October 2016 (day 7) for different modifications of upstream latent heating (simulated heating is multiplied with a factor α).*

Conclusions

- Elimination of upstream latent heating has strong effects on blocking dynamics, but there is also substantial case-to-case variability.
- These effects are due to a combination of two processes: the direct injection of air masses with low PV into the upper troposphere in strongly ascending airstreams, and the indirect effect owing to the interaction of the associated divergent outflow with the upper-level PV structure.
- An accurate parameterization of cloud processes in atmospheric models is crucial for adequately representing blocking dynamics.

References:

[1] Pfahl, S., C. Schwierz, M. Croci-Maspoli, C. M. Grams, and H. Wernli, 2015. Importance of latent heat release in ascending air streams for atmospheric blocking. *Nature Geosci*. **8**, 610-614, doi:10.1038/ngeo2487.

[2] Steinfeld, D. and S. Pfahl, 2019. The role of latent heating in atmospheric blocking dynamics – a global climatology. *Clim. Dyn.*, doi:10.1007/s00382-019-04919-6.

[3] Steinfeld, D., M. Boettcher, R. Forbes, and S. Pfahl, 2020. The sensitivity of atmospheric blocking to changes in upstream latent heating – numerical experiments. *Weather and Climate Dynamics,* doi.org/10.5194/wcd-2020-5