The role of upper vs. lower tropospheric baroclinicity on severe storms over Central Europe and Iceland: Observational results and climate scenarios

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Motivation

Fig. 1: Number of relevant natural loss events in Europe from 1980 until 2018 for geophysical events (red), meteorological events (green), hydrological events (blue) and climatological events (orange) (Munich RE, 2019).
Motivation

**Fig. 2:** Ensemble mean for zonal atmospheric mean temperature changes [°C] for RCP2.6 (left), RCP4.5 (middle) and RCP8.5 (right) for 2081-2100 in comparison to 1986-2005 (see IPCC (2013) Fig. 12.12).
Motivation

Study Questions

a) How do severe storms change in future climate in the used data sets?

b) Are there significant connections between baroclinicity and severe storm parameters and different are they in the upper and lower troposphere?

c) Does the connection between baroclinicity and severe storms various in the future climate compared to present climate?
Data

• Winter season for storms October to March (ONDJFM)

Reanalysis: ERA-interim
• 1979/80 to 2009/10
• Resolution: 0.75°
• 6hr: psl, ua, va, ta, zg

Model: MPI-ESM-LR
• historical: 1969/70 to 1999/2000
• RCP 4.5: 2069/70 to 2099/2100
• Resolution: 1.875°
• 6hr: psl, ua, va
• daily: zg, ta, ua, va

Sensitivity analysis
→ Storm tracking in 850hPa
→ Daily EADY
Methodology – Tracking of Storms/Cyclones

- Wind Storm tracking algorithm like Leckebusch et al. (2008)
- Exceedance of 98th percentile of wind speed

\[
SSIT_{T,K} = \sum_{t}^{T} \sum_{k}^{K} \left[ \left( \max(0, \frac{v_{k,t}}{v_{Perc,k}}) \right)^3 \cdot A_k \right]
\]

- Cyclone tracking with algorithm of Murray and Simmonds (1991)
- \( \max. \nabla^2 \rho \)
Methodology – Eady Growth Rate

- Eady growth rate as indicator for baroclinicity

(Hoskins and Valdes, 1990)

Fig. 3: Scheme of used EADY levels with total regions (color shaded) and resulting mean (dashed line).
Methodology – Eady Growth Rate Composite

Fig. 4: Scheme of used time steps for EADY composite on the example box Iceland with two example storm tracks (red and orange) and the first time step in the box (marked with black circle).

Eady growth rate mean of previous 3 days
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Results – Track Density

Wind Storm Tracks
ERA tracked at 850hPa

Cyclone Tracks
ERA near surface/ at sea level

Fig. 5: Track density of storms (left) and cyclones (right) within a radius of 1000km for ERA tracked in near surface.
Results – Track Density Differences

Wind Storm Tracks

Cyclone Tracks

(MPI-ESM HIST) - (ERA)

Fig. 6: Difference of track density of storms (left) and cyclones (right) between ERA and MPI-ESM HIST, significance at 5% level marked by dots.
Results – Track Density Differences

Wind Storm Tracks
(MPI-ESM RCP4.5) - (MPI-ESM HIST)

Cyclone Tracks

Fig. 7: Difference of track density of storms (left) and cyclones (right) between MPI-ESM RCP4.5 and HIST (bottom), significance at 5% level marked by dots.
Results – Eady Growth Rate Climatology

Fig. 8: EADY \([\text{day}^{-1}]\) winter climatology of ERA for 850hPa (left) and 400hPa (right).
Results – Eady Growth Rate Climatology

Fig. 9: Difference of EADY [day⁻¹] winter climatology between MPI-ESM RCP4.5 and HIST (bottom) for 850hPa (left) and 400hPa (right), significance at 5% level marked by dots.
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Results – Eady Growth Rate Anomalies

Europe-North Composite: 3-day mean of first timestep inside box

Fig. 10: Anomaly between EADY composite in Europe-North and winter climatology in 850hPa (left) and 400hPa (right) for ERA (top) and MPI-ESM HIST (bottom), significance at 5% level marked by dots.
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Results – Eady Growth Rate Anomalies

Europe-North

Climate Signal

850hPa

400hPa

Fig. 11: Anomaly between EADY composite in Europe-North and winter climatology in 850hPa (left) and 400hPa (right) for MPI-ESM RCP4.5, significance at 5% level marked by dots.
Conclusion

• ~ 25 % increase of Eady in lower troposphere
  In observation and historical run
• Northwards shift from lower to upper troposphere
• Extended signals over North Atlantic
• Clear positive anomaly in upper tropospheric baroclinicity in climate scenario
Thank you for your attention!
Bibliography


