Climatology of Vb-cyclones, physical mechanisms and their impact on extreme precipitation over Central Europe

Climate and Environmental Physics
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OESCHGER CENTRE CLIMATE CHANGE RESEARCH

Introduction

- Extreme weather situations are of major relevance for society, since they lead to disastrous events
- Vb-cyclones *(Fig.1)* are an important source of extreme precipitation and large floodings across Central Europe (W. J. Van Bebber (1891))
- State of research: either case studies or simple climatologies are performed
- Thus, an extensive study on physical mechanisms and their impact on extreme precipitation is needed

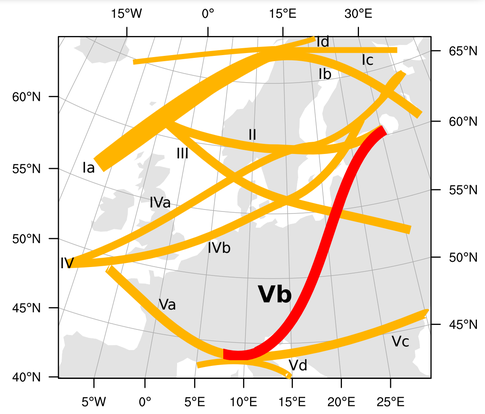

Figure 1: *Orange lines illustrate the main pathways of cyclones between 1876-1880, as defined by W. J. Van Bebber (1891). The Vb-cyclone trajectory is highlighted in red.*

Method

- To identify Vb-events, a cyclone tracking tool (Blender et al. 1997) is applied to geopotential height at 850 hPa (ERA-Interim, 1979-2013, 1.5° x1.5°)
- Automatic filter with a criterion based on origin and end of the track identifies Vb-events
- Paths which cannot be associated with Vb-events are discard
- Composites of cyclones are performed by remapping the variable of interest onto spherical coordinates in a 0.5°x0.5° grid (the centre of the storm is located on the pole)
- The outermost boundary is located 23° off the cyclone centre

Motivation

- 15% of all extreme precipitation days (99 percentile) are triggered by Vb-cyclones
- Vb-cyclones are very rare events, as on average only 2.4 events happen per year
- In the extended summer season 20% of them are associated with high precipitation amounts, while others trigger almost no precipitation (*Fig. 2*)

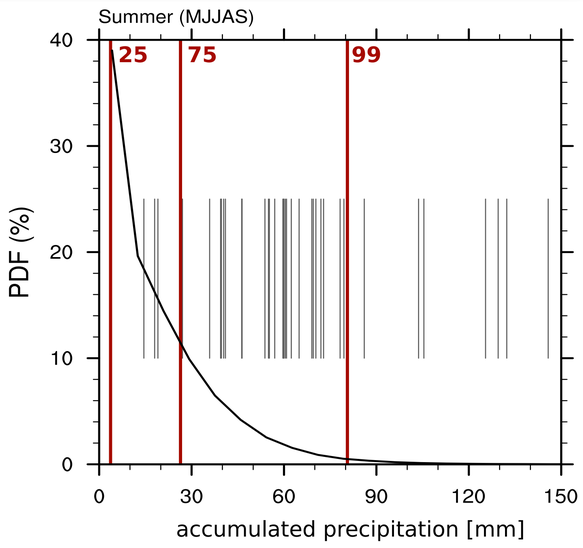

Figure 2: *Probability density function of the accumulated precipitation from ERA-Interim of Vb-events (black line) for the extended summer. The red lines indicate the 25, 75 and 99 percentile from left to right. The vertical, black lines indicate the accumulated precipitation of each Vb-cyclone occurring during summer (MJJAS).*

? What is the reason for the large variability in precipitation during summer Vb-events?

⇨ We study the 10 heaviest precipitation events (HPE) and the 10 weakest precipitation events (WPE) triggered by Vb-cyclones during summer in more detail

Results

Differences in Moisture

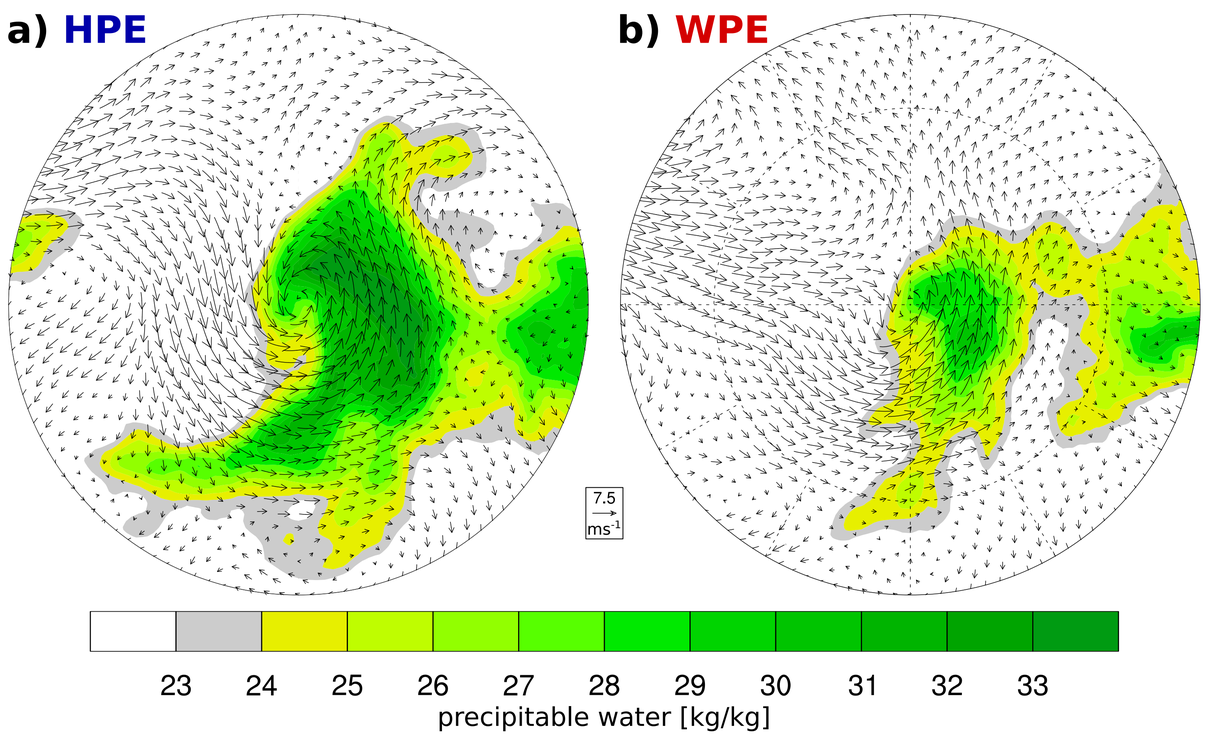

Figure 3: *Composites of precipitable water content [kg/kg, shading] and wind fields at 850 hPa (reference vector 7.5 m/s) during the time step of maximum precipitation for the HPE **(a)** and WPE **(b)** .*

- Mean precipitable water in the atmosphere is much higher for HPE *(Fig. 3a)* than for WPE *(Fig. 3b)*
- But case-to-case variability is very large as some HPE show less precipitable water in the atmosphere than some WPE
- Precipitable water allows no clear separation between the HPE and WPE

Differences in Dynamics

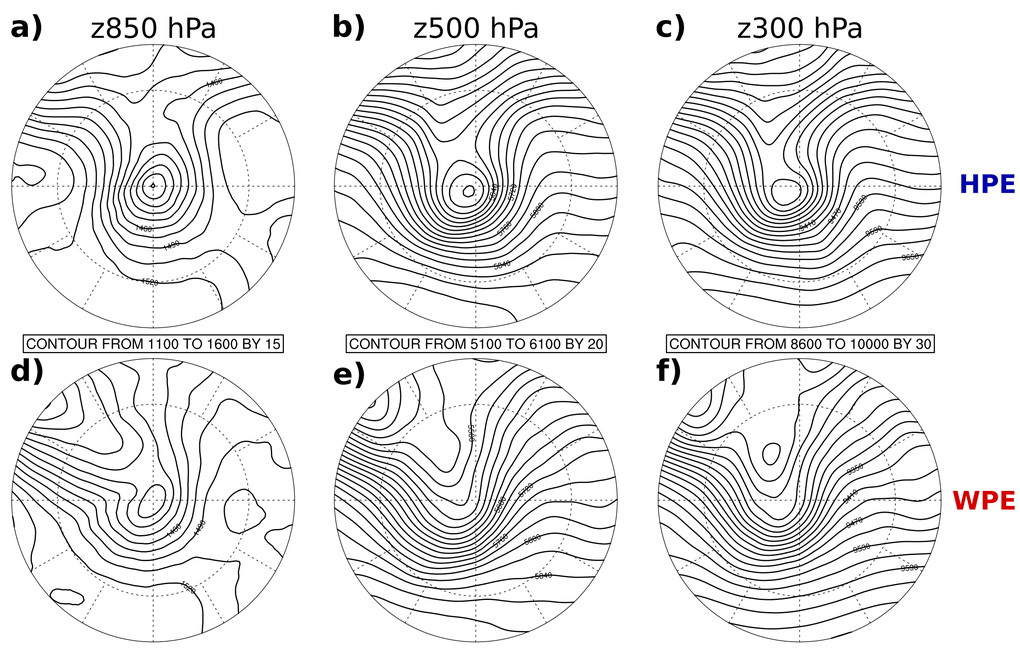

Figure 4: *Average geopotential height at 850 hPa **(a, d)**, 500 hPa **(b, e)** and 300 hPa **(c, f)** for the time step with maximum precipitation of all HPE **(a, b, c)** and WPE **(d, e, f)**.*

- Composites of geopotential height fields on several pressure levels reveal substantial differences in HPE and WPE
- HPE show distinct and deep depression, including a westward tilt of the depression *(Fig. 4a-c)*
- WPE show at lowest level weak depression in the storm's centre *(Fig. 4d)*
- WPE are influenced by a strong depression northwest of the actual cyclone centre *(Fig. 4d-f)*
- Largescale dynamic variables allow a clear distinction between HPE and WPE

Conclusions

- Following a Vb-trajectory is not a sufficient criterion for a cyclone to trigger extreme percipitation amounts
- Additionally, thermodynamic variables, i.e. moisture, play only a minor role in triggering high-impact events
- Largescale dynamics seem to be the major reason for the high variability in summer Vb-events.

? What is the reason for the large variability in precipitation during summer Vb-events?

✗ Differences in the atmospheric moisture content between HPE and WPE

✓ Differences in the geopotential height field between HPE and WPE

References:
Blender R., K. Fraedrich, and F. Lunkeit (1997) Identification of cyclone-track regimes in the North Atlantic, Quart. J. Roy. Meteor. Soc., 123, pp. 727–741
Van Bebber, W. J. (1891) Die Zugstrassen der barometrischen Minima nach Bahnenkarten der Deutschen Seewarte für den Zeitraum von 1870 – 1890, Meteor. Z., 8, pp. 361 – 366

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