Decadal trends of high-intensity precipitation events and relation to atmospheric circulation in Central Germany

Johannes Damster[1], Andreas Hoy[2], Jürg Luterbacher[1]

[1] *Justus-Liebig-University Giessen, Department of Geography, Section: Climatology, Climate Dynamics and Climate Change, Senckenbergstr. 1, 35390 Gießen, Germany*
[2] *Hessian Agency for Nature Conservation, Environment and Geology, Rheingaustr. 186, 65203 Wiesbaden, Germany*

RESEARCH QUESTIONS

- Which trends appear in high-intensity precipitation events, comparing temporal high-resolution data (5min, 1h, 6h) with daily precipitation data in Central Germany (period 1961 to 2015)
- How does atmospheric circulation impacts the occurrence of high-intensity precipitation events, comparing precipitation data with 5min and daily resolution?

METHODS

- **Selection criteria of precipitation stations:**
  - ➢ Central German stations with…
  - …as little as possible data gaps in extended summer season (May to September)
  - …no considerable shifts in station location and environment
- **Linear regression (LR) and Mann-Kendall tendency test (MK)**
- **"High-intensity precipitation event":**

Temporal resolution	Threshold value	Origin
5min	5 mm	Lauer and Bendix 2004
1h	15 mm	Warning Level 2 - DWD
6h	20 mm	Warning Level 2 - DWD
24h	30 mm	Warning Level 2 - DWD

Tab. 1: Threshold values for different temporal resolutions and their origins (Lauer & Bendix 2004 and DWD 2018).

DATA

- **Precipitation**
  - ➢ Stations: 19 in Central Germany
  - ➢ Temporal resolution: from 5 minutes
  - ➢ Time frame: 1961 to 2015
  - ➢ Season: May to September
  - ➢ Origin: DWD (Climate Data Centre)

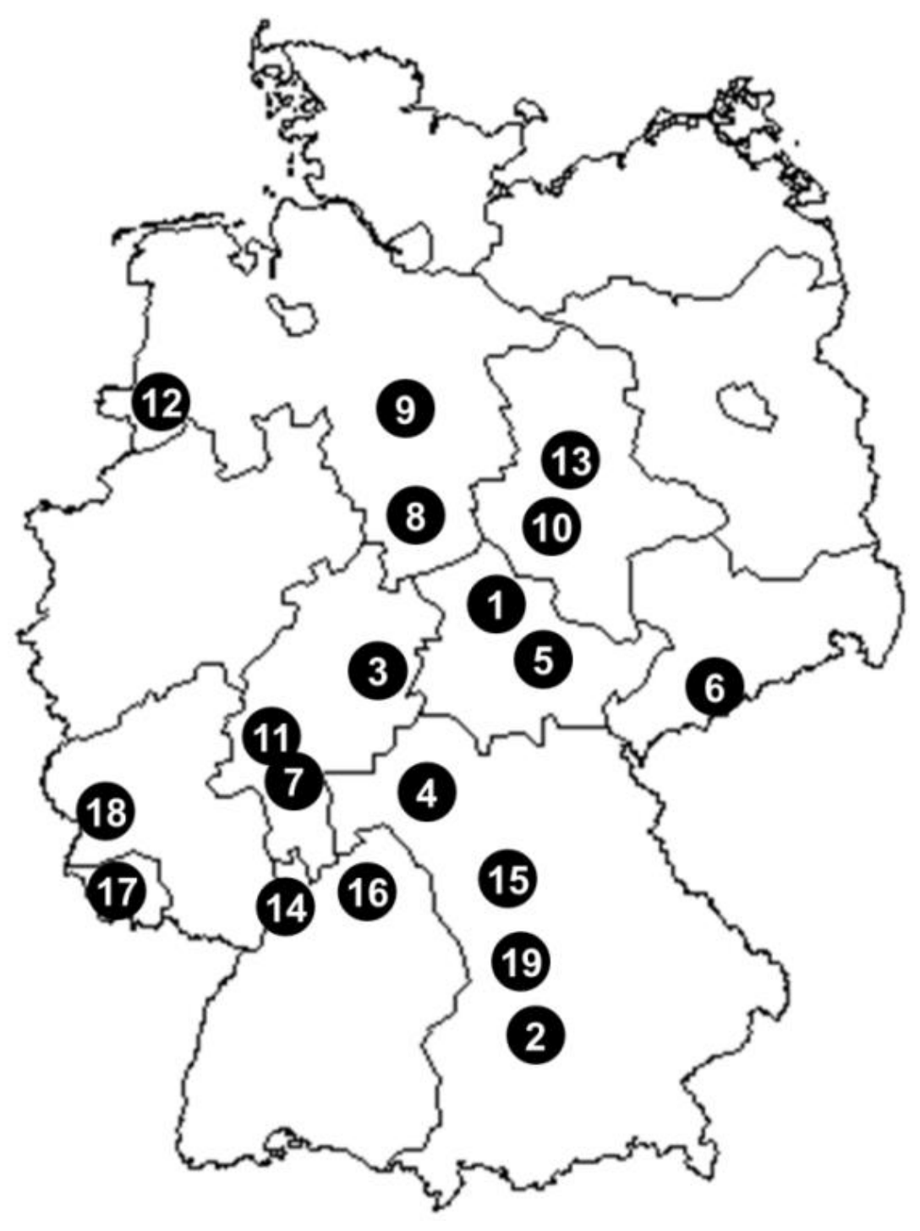

Fig. 1: Location of used Central German stations (see table 3 for station names).

- **Atmospheric circulation**
  - ➢ Daily European "Grosswetterlagen"
  - ➢ Manual classification **(GWLc)** concept by Baur et al. (1944) and Hess and Brezowsky (1977); data Werner and Gerstengarbe (2010)
  - ➢ Automated classification **(SVGc)** concept by P. James, see Hoy et al. (2012)

Grosswetterlage (GWL)	Abbrev.	Inflow
Anticyclonic Westerly	WA	W
Cyclonic Westerly	WZ	
South-Shifted Westerly	WS	
Westerly, Block Eastern Europe	WW	
Anticyclonic South-Westerly	SWA	SW
Cyclonic South-Westerly	SWZ	
Anticyclonic North-Westerly	NWA	NW
Cyclonic North-Westerly	NWZ	
High over Central Europe	HM	–
Zonal Ridge across Central Europe	BM	
Low (Cut-Off) over Central Europe	TM	
Anticyclonic Northerly	NA	N
Cyclonic Northerly	NZ	
Icelandic High, Ridge Central Europe	HNA	
Icelandic High, Trough Central Europe	HNZ	
High over the British Isles	HB	
Trough over Central Europe	TRM	
Anticyclonic North-Easterly	NEA	NE
Cyclonic North-Easterly	NEZ	
Scandinavian High, Ridge Central Europe	HFA	E
Scandinavian High, Trough Central Europe	HFZ	
High Scandinavian-Iceland, Ridge	HNFA	
High Scandinavian-Iceland, Trough	HNFZ	
Anticyclonic South-Easterly	SEA	SE
Cyclonic South-Easterly	SEZ	
Anticyclonic Southerly	SA	S
Cyclonic Southerly	SZ	
Low over the British Isles	TB	
Trough over Western Europe	TRW	

Tab. 2: Scheme of Grosswetterlagen (Hoy et al. 2012).

RESULTS

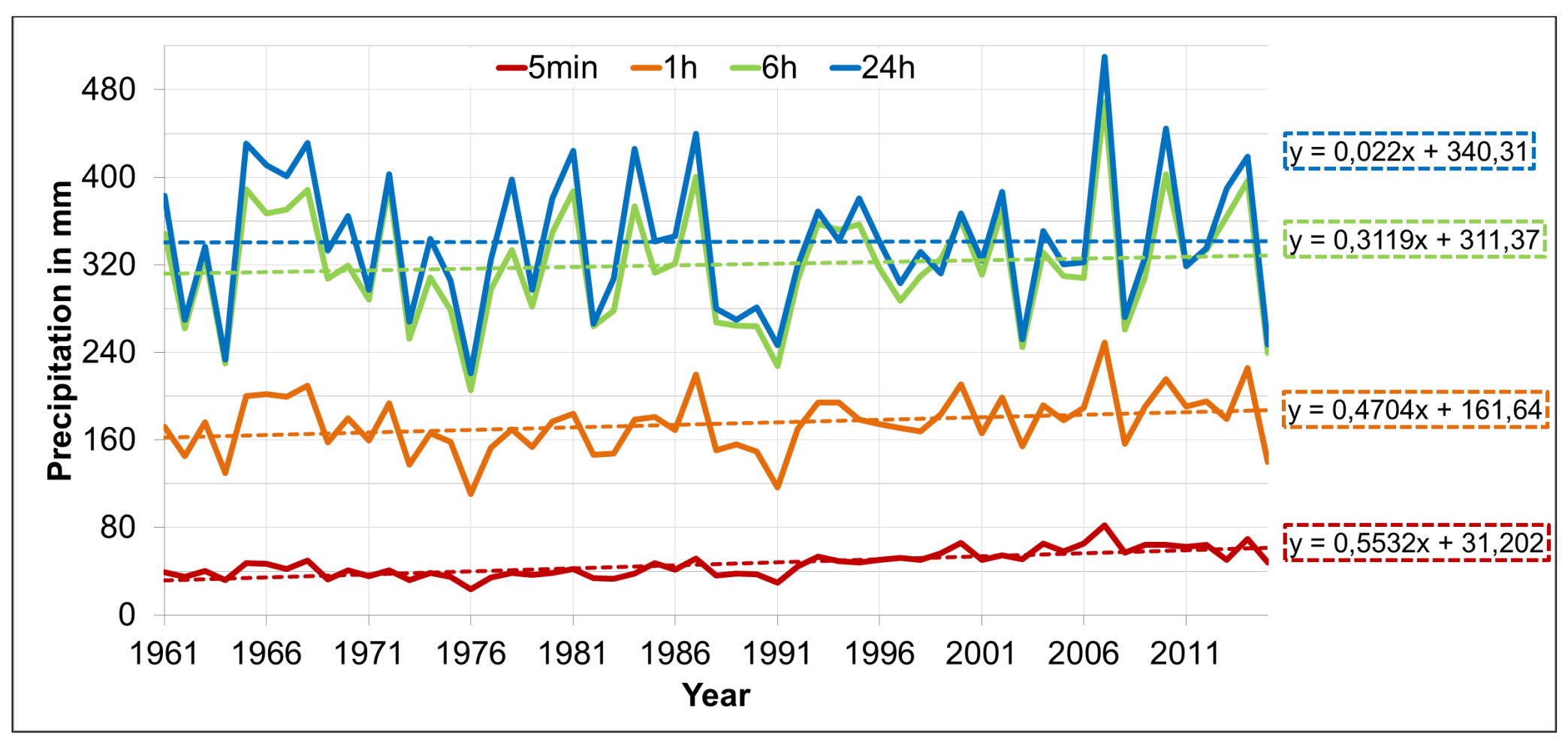

Fig. 2: Seasonal (May – September) daily added maximum precipitation for four different temporal resolutions, averaged over all stations during the period 1961 to 2015 (in mm).

Tab. 3: Linear trends of seasonal daily added maximum precipitation for different temporal resolutions. Bold / underlined indicates significant linear regression / Mann-Kendall tendency test.

Station	Map ID	5min	1h	6h	24h
Artern	1	**0,51**	**0,72**	0,83	1,03
Augsburg	2	**0,57**	0,36	-0,09	-0,83
Bad Hersfeld	3	**0,77**	**0,89**	0,66	0,31
Bad Kissingen	4	**0,47**	0,41	0,21	-0,37
Erfurt	5	**0,59**	**0,81**	0,82	1,13
Fichtelberg	6	**0,41**	**0,71**	1,25	1,33
Frankfurt	7	**0,65**	0,59	-0,04	-0,55
Göttingen	8	**0,69**	0,64	0,36	0,20
Hannover	9	**0,25**	-0,02	-0,09	-0,34
Harzgerode	10	**0,33**	0,46	0,80	0,67
Kleiner Feldberg	11	**0,90**	**0,79**	0,15	-0,37
Lingen	12	**0,78**	0,22	0,07	-0,37
Magdeburg	13	**0,29**	0,55	1,05	1,11
Mannheim	14	**0,71**	0,33	0,03	-0,55
Nürnberg	15	**0,56**	0,51	0,32	-0,07
Oehringen	16	**0,64**	0,35	0,00	-0,84
Saarbrücken	17	**0,54**	0,29	0,03	-0,50
Trier	18	**0,36**	0,12	-0,04	-0,36
Weissenburg	19	**0,58**	0,69	0,69	0,38
Averaged	–	**0,55**	0,47	0,31	0,02

Trends (intensity)

- 5min-data: significant increase in intensity for almost all stations
- 1h-data: fewer stations with significant increase, but generally increasing trends
- 6h-data and daily data: no clear and significant trends

→ Increase in high-resolution data may be connected to a) more intense and/or higher number of convective showers and b) better observation methods for high-resolution precipitation

→ More research needed to find out extent of "real" climate signal

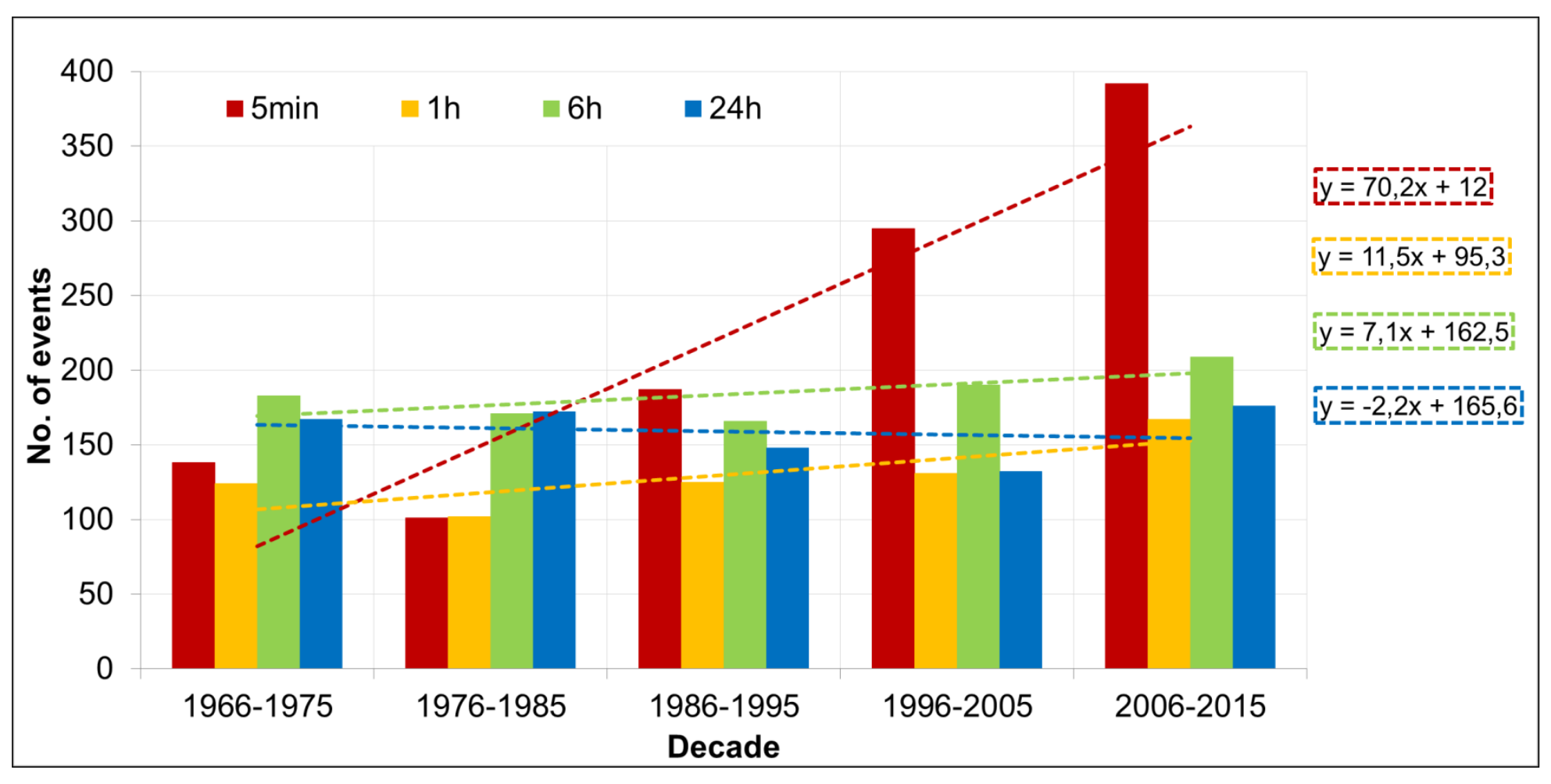

Fig. 3: Decadal number of high-intensity precipitation events and linear trends for different temporal resolutions (starting with 1966 – 1975, ending with 2006 – 2015)

Trends (occurrence)

- Very strong increase for 5min-events, especially during last two periods → may be strongly related to change in measuring techniques from beginning of 1990s (see discussion in previous box)
- Moderate increase for 1h / 6h
- No trends for daily data

Annual cycle (occurrence)

- 5min-events: mainly driven by convection – peak in mid-July indicates importance of solar altitude and higher air temperatures
- Daily events: driven by convection (high level from end of May to beginning of August) and atmospheric circulation (peaks beginning of June and mid/end of July)

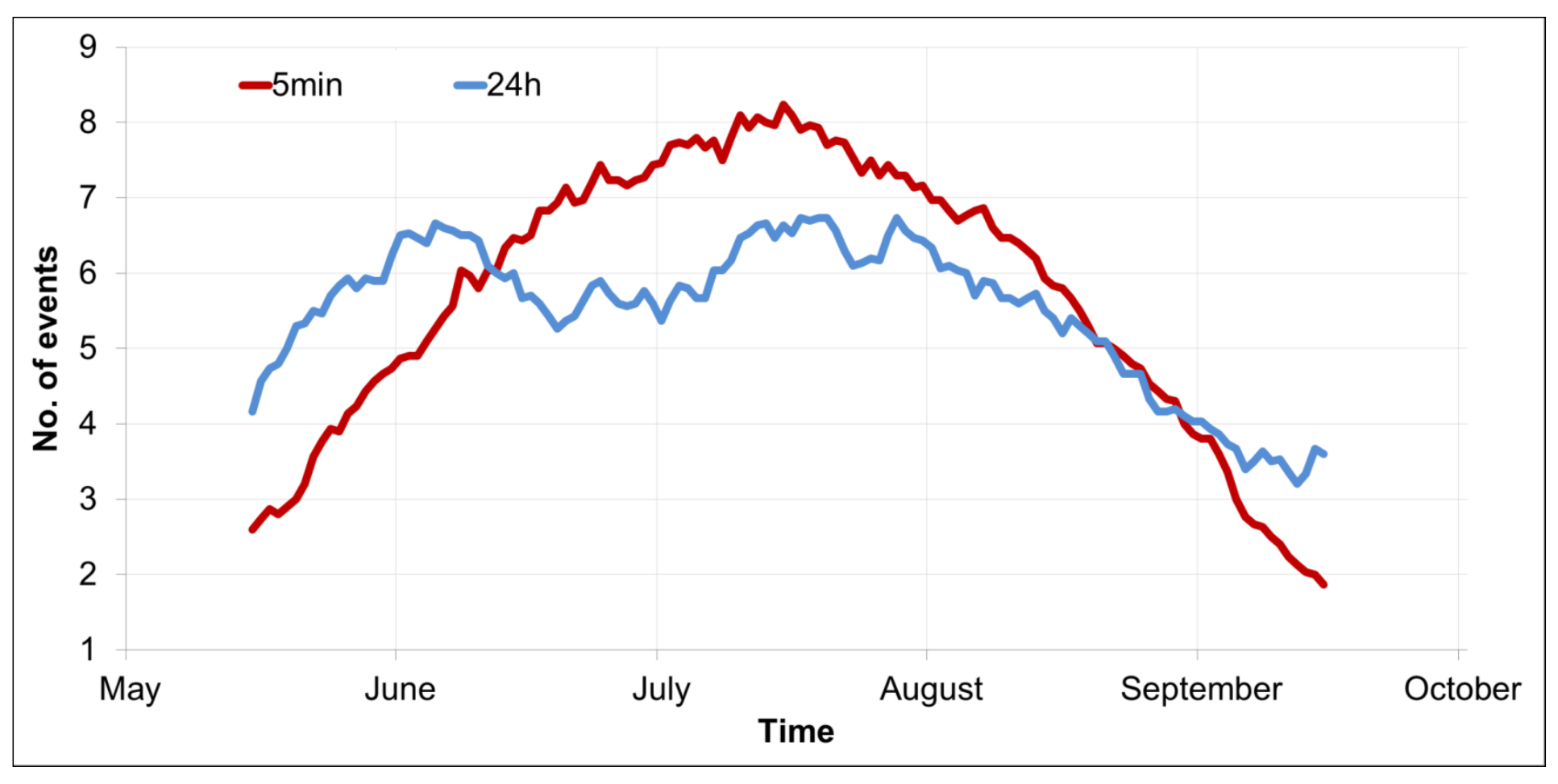

Fig. 4: Absolute daily number of high-intensity precipitation events for 5min (RR≥ 5mm) and daily resolution (RR≥30 mm) within 1961 – 2015 (30-day-smoothing).

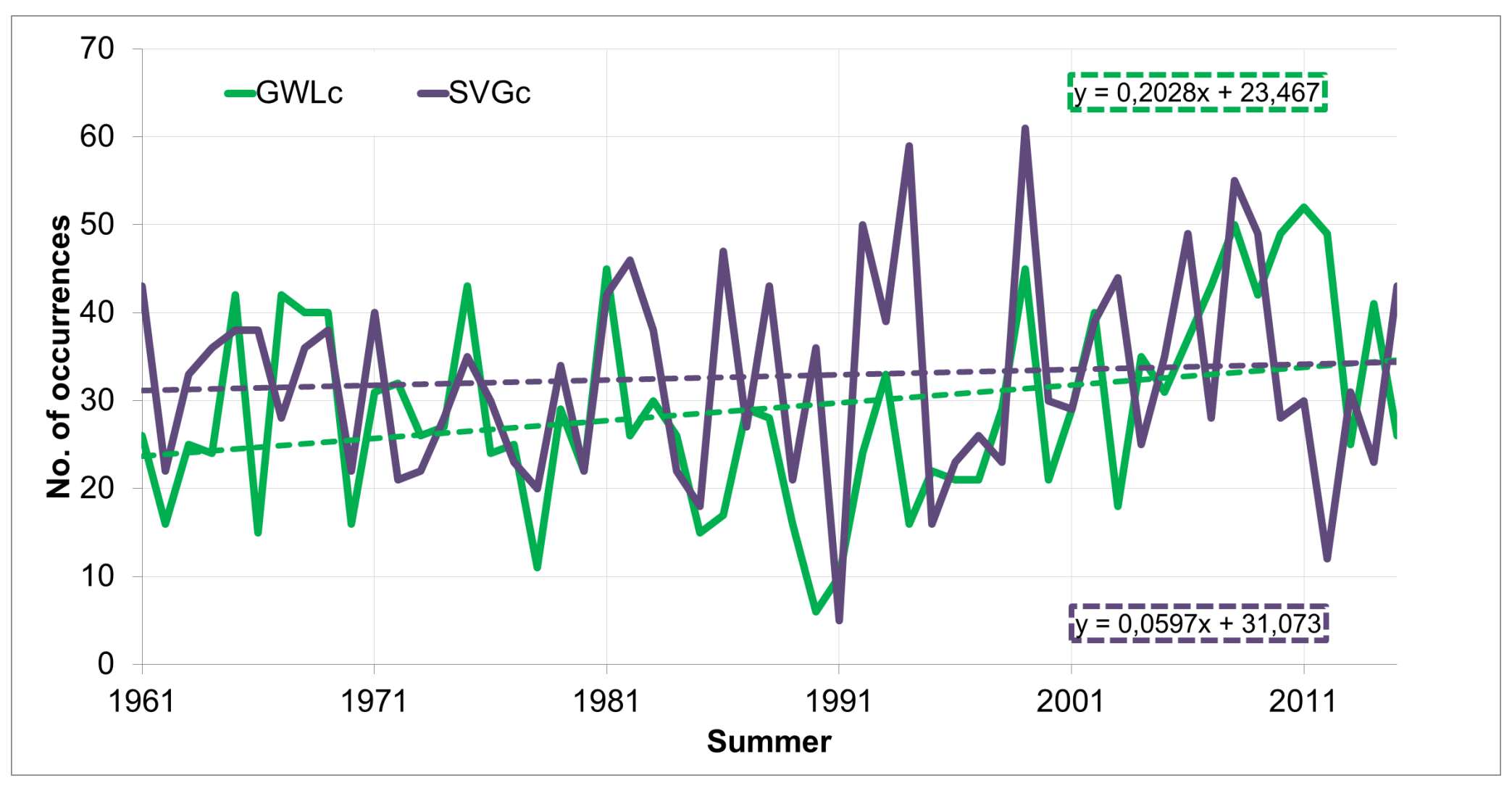

Fig. 6: Frequency of highly convection-relevant Grosswetterlagen (see table 4) during May – September and trends per year for GWLc (green) and SVGc (purple).

Trends convection-relevant Grosswetterlagen

→ For both classifications: non-significant frequency increase, but possible backup for more events from the 1990s

CONCLUSIONS

Strong increase in high-intensity precipitation events of short duration (especially 5min, but also 1h)

- Clarification of causes still needed (climatology vs. improvement of recording equipment)
- Grosswetterlagen with southern component are more likely to cause these events, through the transport of warm air.
- No significant increase in frequency of "highly convection-relevant" Grosswetterlagen, but possible impact from 1990s (more research needed).

REFERENCES:

- Baur F., Hess P., Nagel H. (1944): Kalender der Großwetterlagen Europas 1881–1939. Bad Homburg v. d. H., 35 pp.
- DWD (2018): Warnkriterien. Available via: www.dwd.de/DE/wetter/warnungen_aktuell/kriterien/warnkriterien.html?nn=605882.
- Hess, P., Brezowsky H. (1977): Katalog der Großwetterlagen Europas (1881-1976). 3., verbesserte und ergänzte Auflage. Berichte des Deutschen Wetterdienstes 113.
- Hoy A., Jaagus J., Sepp M., Matschullat J. (2012): Spatial response of two European atmospheric circulation classifications (data 1901–2010). Theor Appl Climatol (2013) 112: 73–88.
- Lauer W., Bendix J. (2004): Klimatologie. 2., neu bearbeitete Auflage. Braunschweig.
- Werner P.C., Gerstengarbe F.W. (2010): Katalog der Großwetterlagen Europas (1881-2009). 7., verbesserte und ergänzte Auflage. Berichte des Deutschen Wetterdienstes 119.

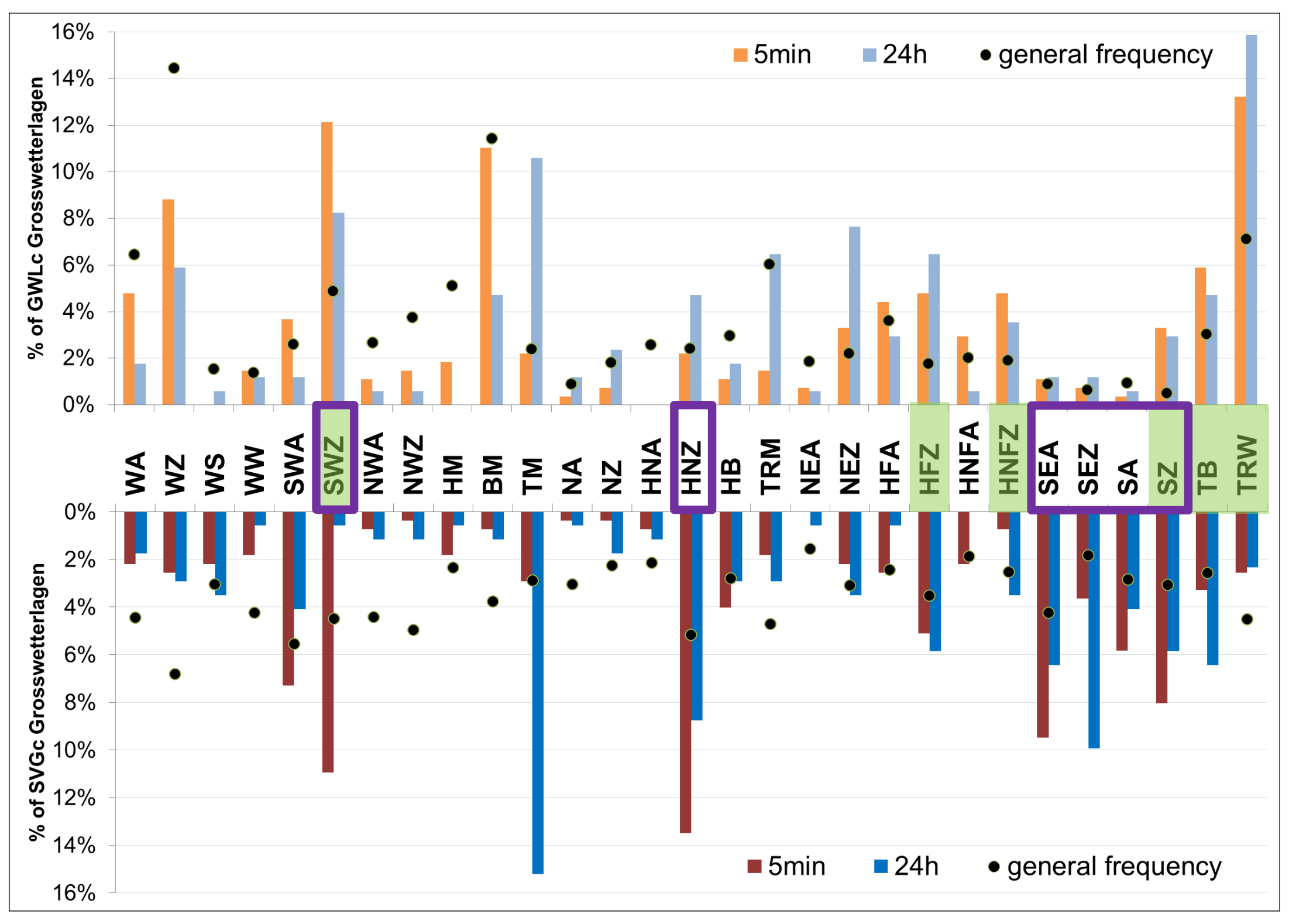

Fig. 5: Relative frequency of high-intensity precipitation events within Grosswetterlagen of GWLc (top) and SVGc (bottom) for May – September 1961 – 2015. Black dots indicate Grosswetterlagen frequency [% of all days]. Green (GWLc) / purple (SVGc) markings show highly convection-relevant Grosswetterlagen selected according to table 4.

SVGc (occurrence)

5min-events

- High frequency of Grosswetterlagen with southeastern, southern and southwestern (warm) inflow and
- HNZ = relevance because of influence of a) cold air pool over western Europe with cold air stream from northern Europe or b) disturbances of the southern sector of the Atlantic frontal zone (Werner and Gerstengarbe 2010).

Daily events

- Often connected to TM, HNZ and south- and southeasterlies.

GWLc (occurrence)

5min-events

- High frequency of Grosswetterlagen WZ, BM, TRW, TRM and WA (different distribution than SVGc).
- No strong dominance of Grosswetterlagen with similar inflow direction like for SVGc.

Daily events

- Mostly onnected to trough conditions, TM and cyclonal circulation types of various inflow directions.

Grosswetterlage	GWLc	SVGc	Inflow
WA	2%	2%	W
WZ	2%	1%	
WS	0%	2%	
WW	3%	1%	
SWA	5%	4%	SW
SWZ	**8%**	**8%**	
NWA	1%	1%	NW
NWZ	1%	0%	
HM	1%	3%	–
BM	3%	1%	
TM	3%	3%	
NA	1%	0%	N
NZ	1%	1%	
HNA	0%	1%	
HNZ	3%	**9%**	
HB	1%	5%	
TRM	1%	1%	
NEA	1%	0%	NE
NEZ	5%	2%	
HFA	4%	3%	E
HFZ	**9%**	5%	
HNFA	5%	4%	
HNFZ	**8%**	1%	
SEA	4%	**7%**	SE
SEZ	4%	**7%**	
SA	1%	**7%**	S
SZ	**21%**	**9%**	
TB	**6%**	4%	
TRW	**6%**	2%	

Tab. 4:. Relative frequency of days with high-intensity 5min-events at 2 or more (of 19) stations per Grosswetterlage within GWLc and SVGc. Grosswetterlagen with frequencies >5% are defined as "highly convection-relevant" as used in fig. 5 and 6.

EMS Annual Meeting: European Conference for Applied Meteorology and Climatology 2018 | 3–7 September 2018 | Budapest, Hungary