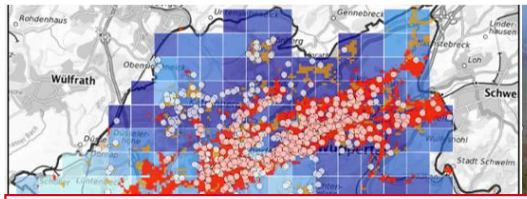
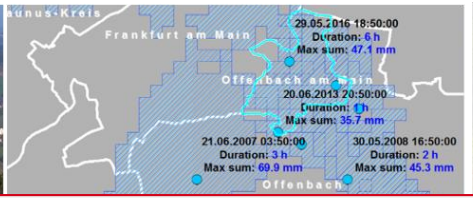
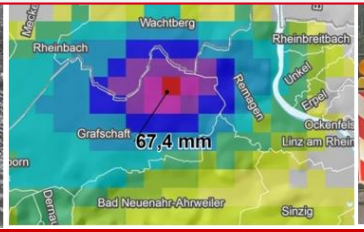
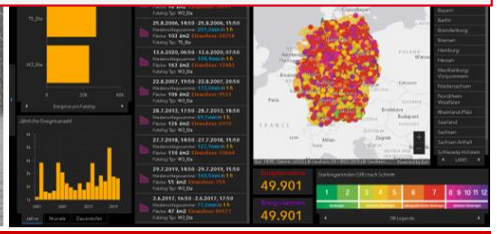
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Spatio-temporal patterns and extremity assessment **of heavy rainfall events in Germany**, derived **from a radar-based catalogue** (CatRaRE, 2001-2020)

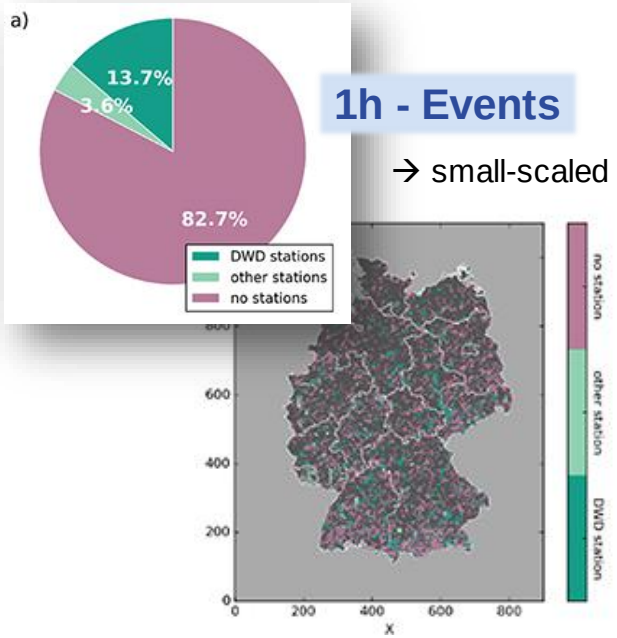



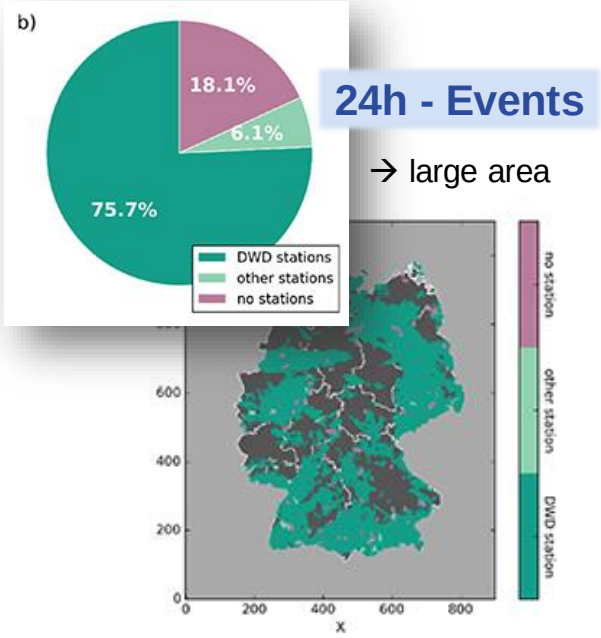



Ewelina Walawender, Dr. Katharina Lengfeld, Dr. Tanja Winterrath, Elmar Weigl, Dr. Andreas Becker

Deutscher Wetterdienst, Hydrometeorology, Offenbach am Main, Germany

Percentage of extreme events (2001-2018) that were measured or missed by the DWD precipitation stations





→ percentage of detected events decreases with shorter durations

→ only **33% of all events have been recorded** by rain gauges (more than **75% observed for D = 24h**)

→ the **events of short duration are rarely recorded** by the point measurements (**82.7% missed for D = 1 h**)

MORE: Katharina Lengfeld et al, 2020
Environ. Res. Lett.15 08500,
https://doi.org/10.1088/1748-9326/ab98b4

Spatio-temporal patterns and extremity assessment of heavy rainfall events in Germany, derived from a radar-based catalogue (CatRaRE, 2001-2020)

1. Radar Climatology
2. Catalogue of extreme precipitation events
3. Spatio-temporal patterns
4. Applications of the CatRaRE Catalogue

1 Radar climatology (RADKLIM)

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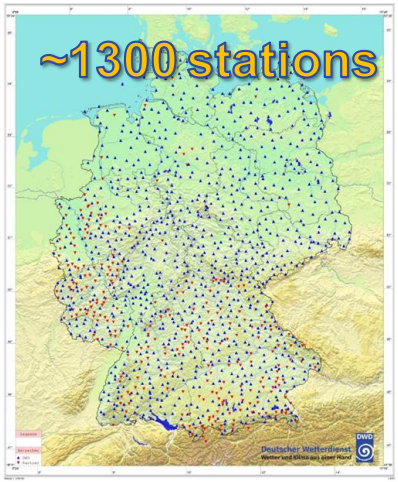
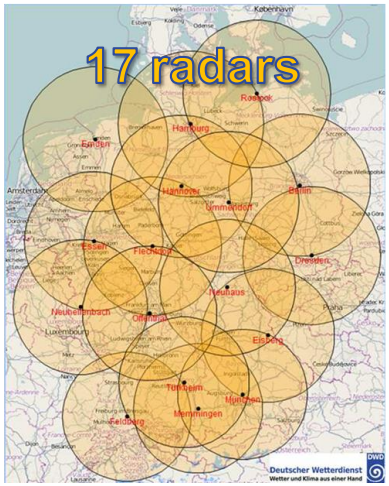
- → **20 years (2001 - 2020)** of re-processed radar data **for Germany**
- → with **1 km** spatial and **1 hour** temporal resolution
- → radar-based reflectivity measurements adjusted to hourly station-based precipitation totals and corrected for typical measurement errors applying specific climatological correction methods

RADOLAN (real-time)



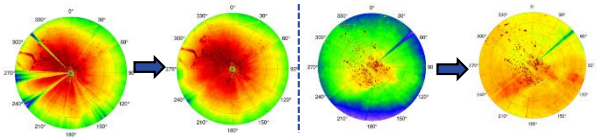
+



RADKLIM (annualy updated)

+

→ **Correction procedures**
(Spoke, Distance, Clutter. . .)



→ **Additional weather stations**
(Better quantitative data)

Download: opendata.dwd.de
DOI: 10.5676/DWD/RADKLIM_RW_V2017.002

Spatio-temporal patterns and extremity assessment of heavy rainfall events in Germany, derived from a radar-based catalogue (CatRaRE, 2001-2020)

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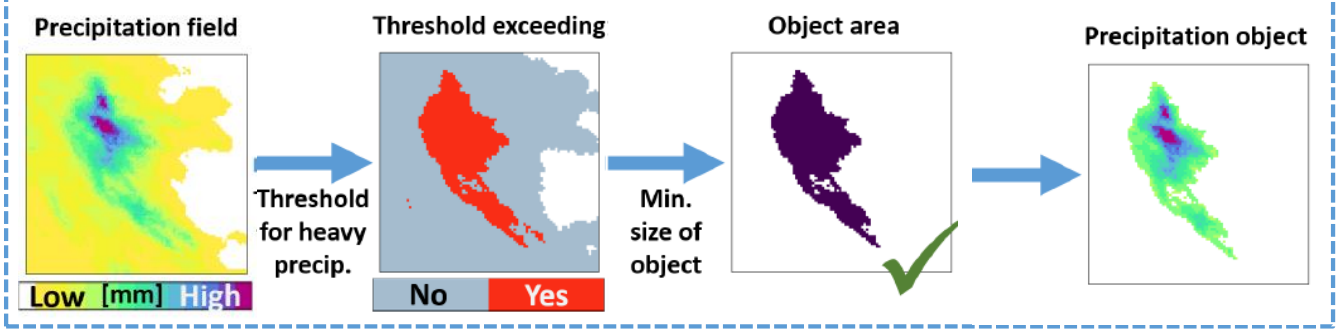
How to define an extreme event?

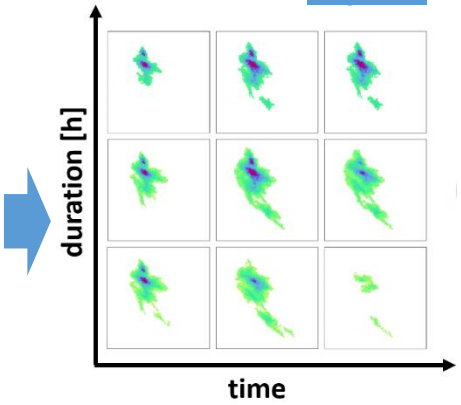
- **What is extreme?**
  - Precipitation rates (pixel) with **return periods** of at least **5 years** ***(=T5 Catalogue)*** *or*
  - Precipitation rates (pixel) exceeding the **DWD warning level 3** ***(=W3 Catalogue)***
- **11 durations** between 1 and 72 hours (1, 2, 3, 4, 6, 9, 12, 18, 24, 48 and 72 hours)
- Duration-dependent **minimal size** of a contiguous area

objects for each analyzed duration and time step

For each time step (= durations 1 to 72h):



All detected objects:

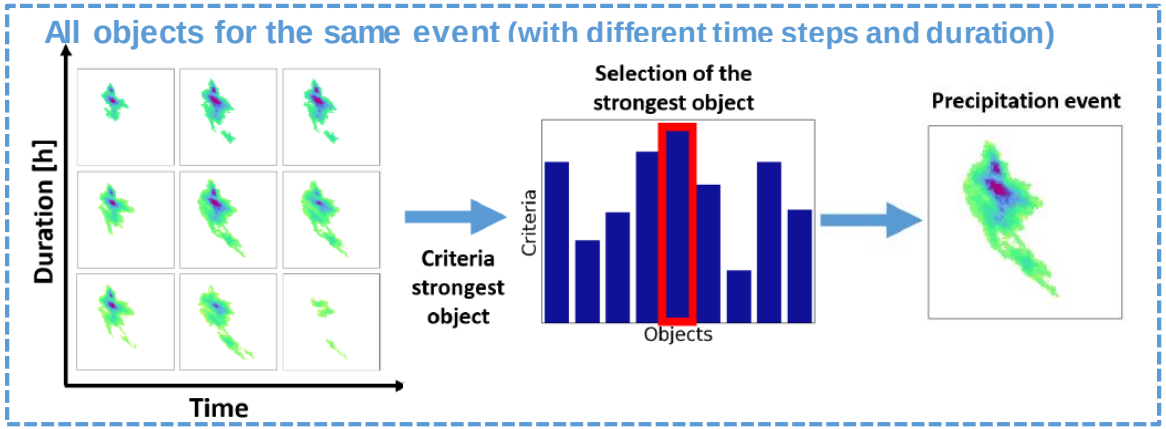


From objects to an extreme event?

➔ How to define an independent event ?

- ➔ Selection of the objects with **highest extremity*:** combination of mean **return period** and **area**
- ➔ **No spatial overlapping** of the detected objects of different durations
- ➔ **Temporal minimum distance** referring to the lower duration (but at least 4h)

events with characteristic duration



*** EXTREMITY ($E_{T,A}$)**

based on concept of Weather Extremity Index (WEI) by Müller and Kaspar

Source: *Müller, M. and Kaspar, M.: Event-adjusted evaluation of weather and climate extremes, Nat. Hazards Earth Syst. Sci., 14, 473-483, doi:10.5194/nhess-14-473-2014, 2014*

2 Catalogue of extreme precipitation events

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For all detected events the following ATTRIBUTES are determined:

- catalogue type, event ID
- **temporal parameters**: start and end time, duration
- **spatial parameters**: affected area, coordinates, state, county and district of the grid cell with maximum precipitation, proportion of the event area [%] in Germany
- **precipitation statistics**: mean and maximum precipitation, return period, heavy precipitation index (SRI) and extremity (E_{ta}) within the event area
- **meteorological parameters**: weather type at start and end time of the event according to DWD's objective weather classification, 21- and 30-days antecedent precipitation index
- **additional geographical variables**: population, degree of settlement, degree of sealing, land use, elevation a.s.l. and topographic position index (TPI)

+ extension with other attributes is possible (e.g. for our projects: fire brigades operations, insurance data, air temperature and wind parametres…)

2 Catalogue of extreme precipitation events

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Wetter und Klima aus einer Hand

CatRaRE Catalogues

* CatRaRE_W3_Eta
* CatRaRE_T5_Eta

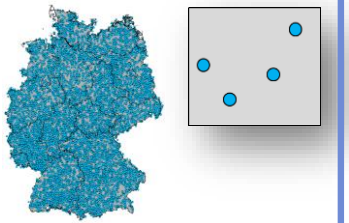
"CatRaRE" → Catalogue of Radar-based heavy Rainfall Events

Tabular form
(.csv File)

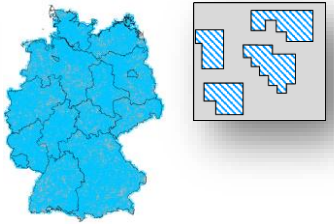
Time	Duration	Area	RRmean	Tmean
200102160550	4	18	46.16	10
200102160850	9	36	61.88	20
200104041550	1	30	38.48	20

File Geodatabase (.gdb)

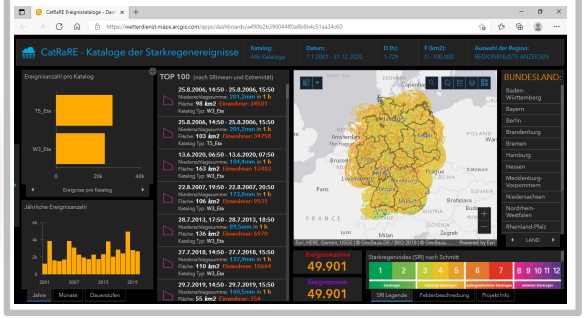
Eventmaxima
(Point Feature Class)



Eventzones
(Polygone Feature Class)



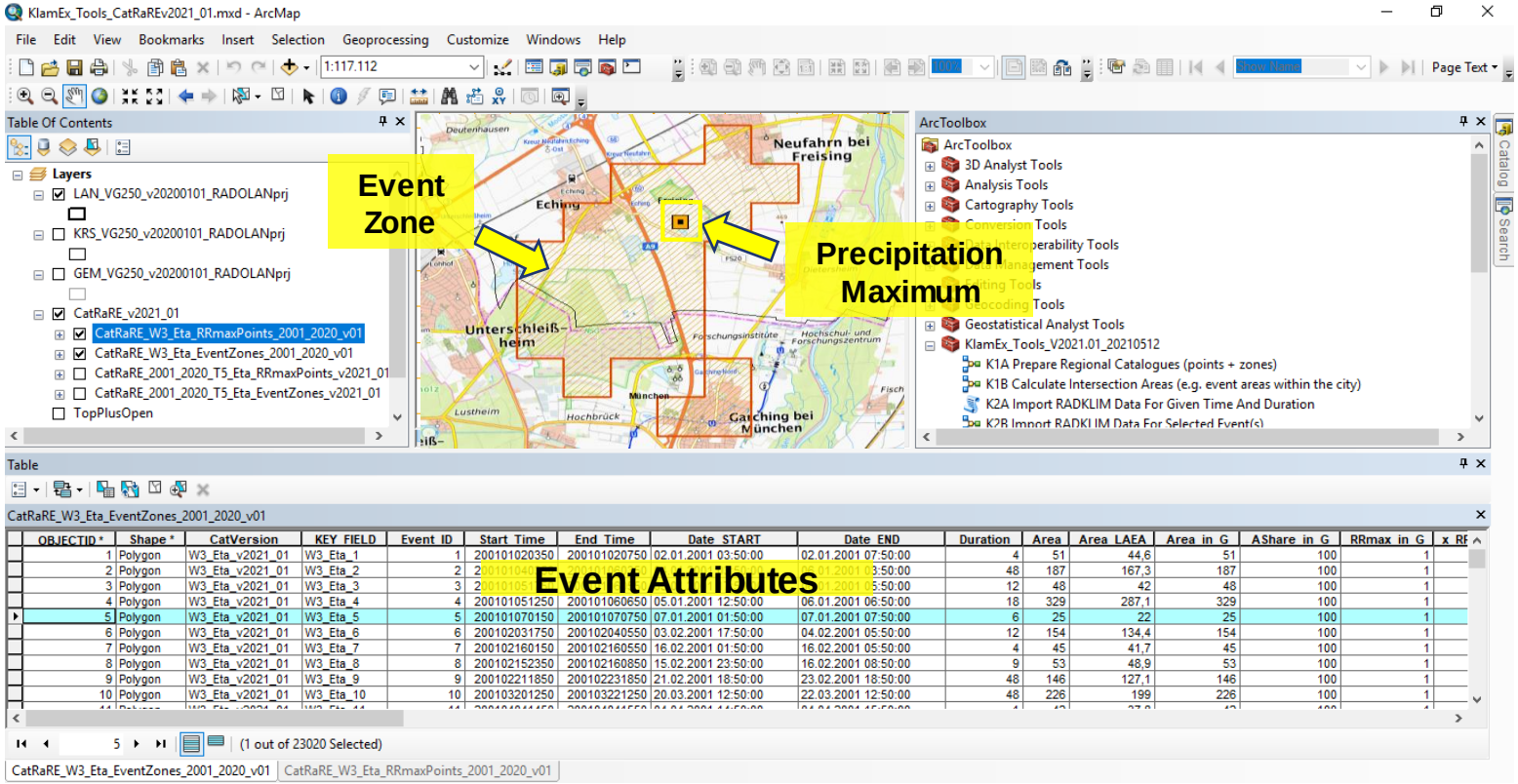
Dashboard (online)



Download:
opendata.dwd.de/climate_environment/CDC/event_catalogues/

2 Catalogue of extreme precipitation events

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



OBJECTID *	Shape *	CatVersion	KEY_FIELD	Event_ID	Start_Time	End_Time	Date_START	Date_END	Duration	Area	Area_LAEA	Area_in_G	AShare_in_G	RRmax_in_G	x_RF
1	Polygon	W3_Eta_v2021_01	W3_Eta_1	1	200101020350	200101020750	02.01.2001 03:50:00	02.01.2001 07:50:00	4	51	44,6	51	100	1	
2	Polygon	W3_Eta_v2021_01	W3_Eta_2	2	200101040350	200101040750	04.01.2001 03:50:00	04.01.2001 07:50:00	48	187	167,3	187	100	1	
3	Polygon	W3_Eta_v2021_01	W3_Eta_3	3	200101050350	200101050750	05.01.2001 03:50:00	05.01.2001 07:50:00	12	48	42	48	100	1	
4	Polygon	W3_Eta_v2021_01	W3_Eta_4	4	200101051250	200101060650	05.01.2001 12:50:00	06.01.2001 06:50:00	18	329	287,1	329	100	1	
5	Polygon	W3_Eta_v2021_01	W3_Eta_5	5	200101070150	200101070750	07.01.2001 01:50:00	07.01.2001 07:50:00	6	25	22	25	100	1	
6	Polygon	W3_Eta_v2021_01	W3_Eta_6	6	200102031750	200102040550	03.02.2001 17:50:00	04.02.2001 05:50:00	12	154	134,4	154	100	1	
7	Polygon	W3_Eta_v2021_01	W3_Eta_7	7	200102160150	200102160550	16.02.2001 01:50:00	16.02.2001 05:50:00	4	45	41,7	45	100	1	
8	Polygon	W3_Eta_v2021_01	W3_Eta_8	8	200102152350	200102160850	15.02.2001 23:50:00	16.02.2001 08:50:00	9	53	48,9	53	100	1	
9	Polygon	W3_Eta_v2021_01	W3_Eta_9	9	200102211850	200102231850	21.02.2001 18:50:00	23.02.2001 18:50:00	48	146	127,1	146	100	1	
10	Polygon	W3_Eta_v2021_01	W3_Eta_10	10	200103201250	200103221250	20.03.2001 12:50:00	22.03.2001 12:50:00	48	226	199	226	100	1	

Working with .gdb format:

ArcGIS ESRI ESRI

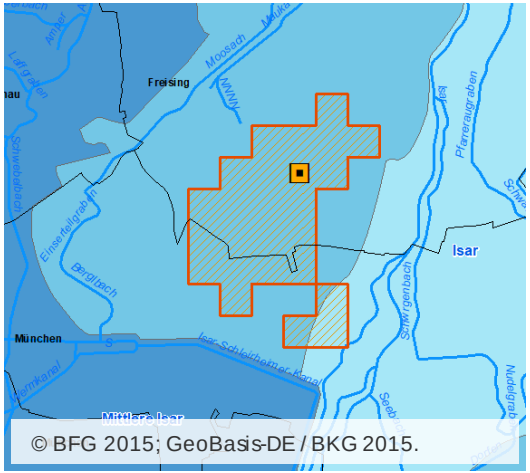
QGIS

GDAL python R

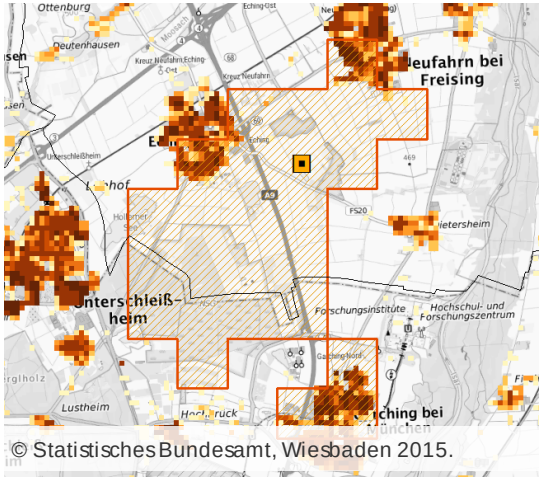
Catalogue of extreme precipitation events

Advantage: Possibility of integration with other geospatial data of various formats and resolutions

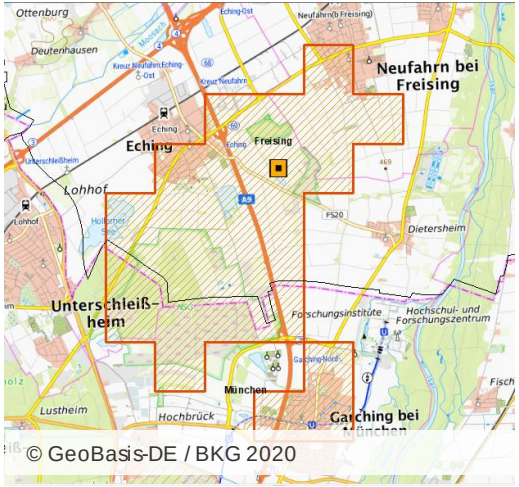
River Basins and Water bodies
(Polygone and Lines - Vector data)



Population density
(100 m Raster)



Topographic map - TopPlus Open
(WMTS - Web Map Tile Service)



2 CatRaRE Dashboard (online)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

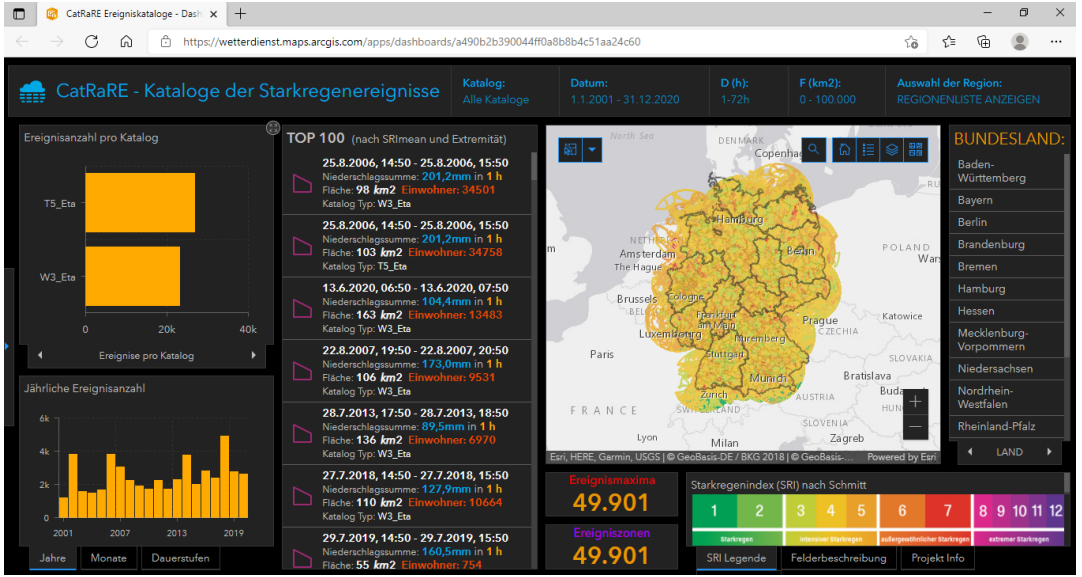
https://arcg.is/1HDqH5

oder:

https://wetterdienst.maps.arcgis.com/apps/dashboards/a490b2b390044ff0a8b8b4c51aa24c60

Or go to:

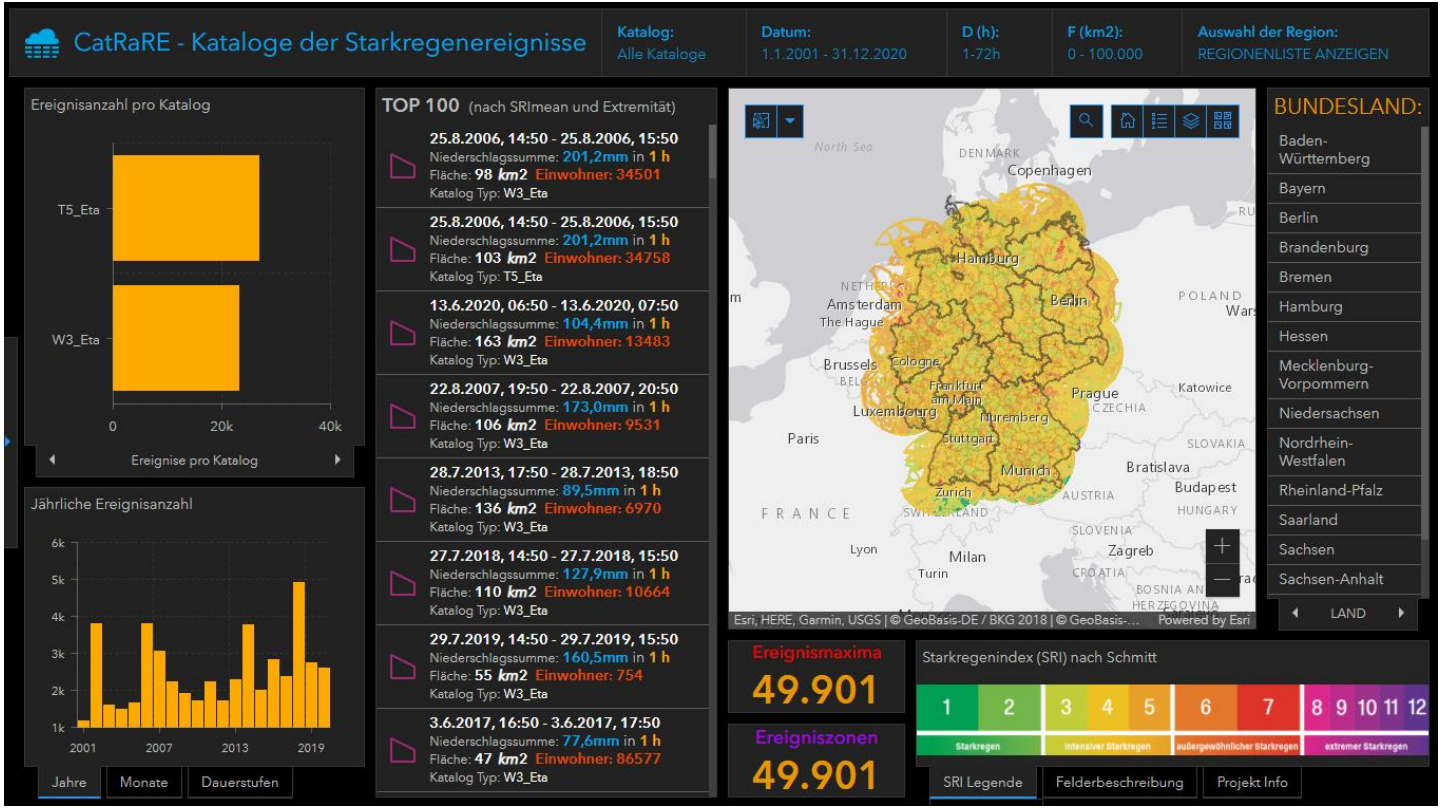
dwd.de/klamex



ⓘ ***Hint***: *open the Dashboard-Link in a new Browser's Window (~~Internet Explorer~~)*

2 CatRaRE Dashboard (online)

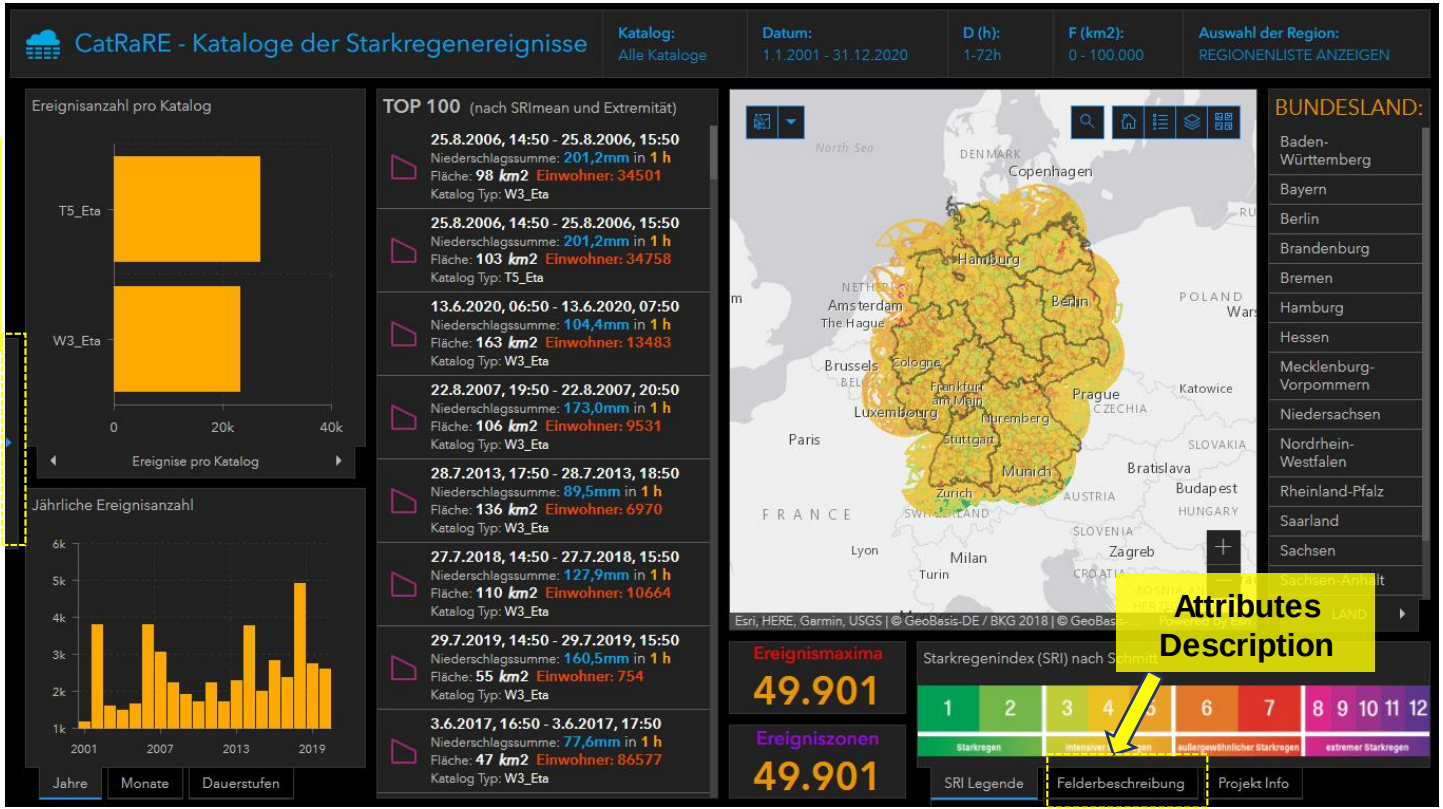
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



2 CatRaRE Dashboard (online)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

HELP (Method description + Links to the Data)



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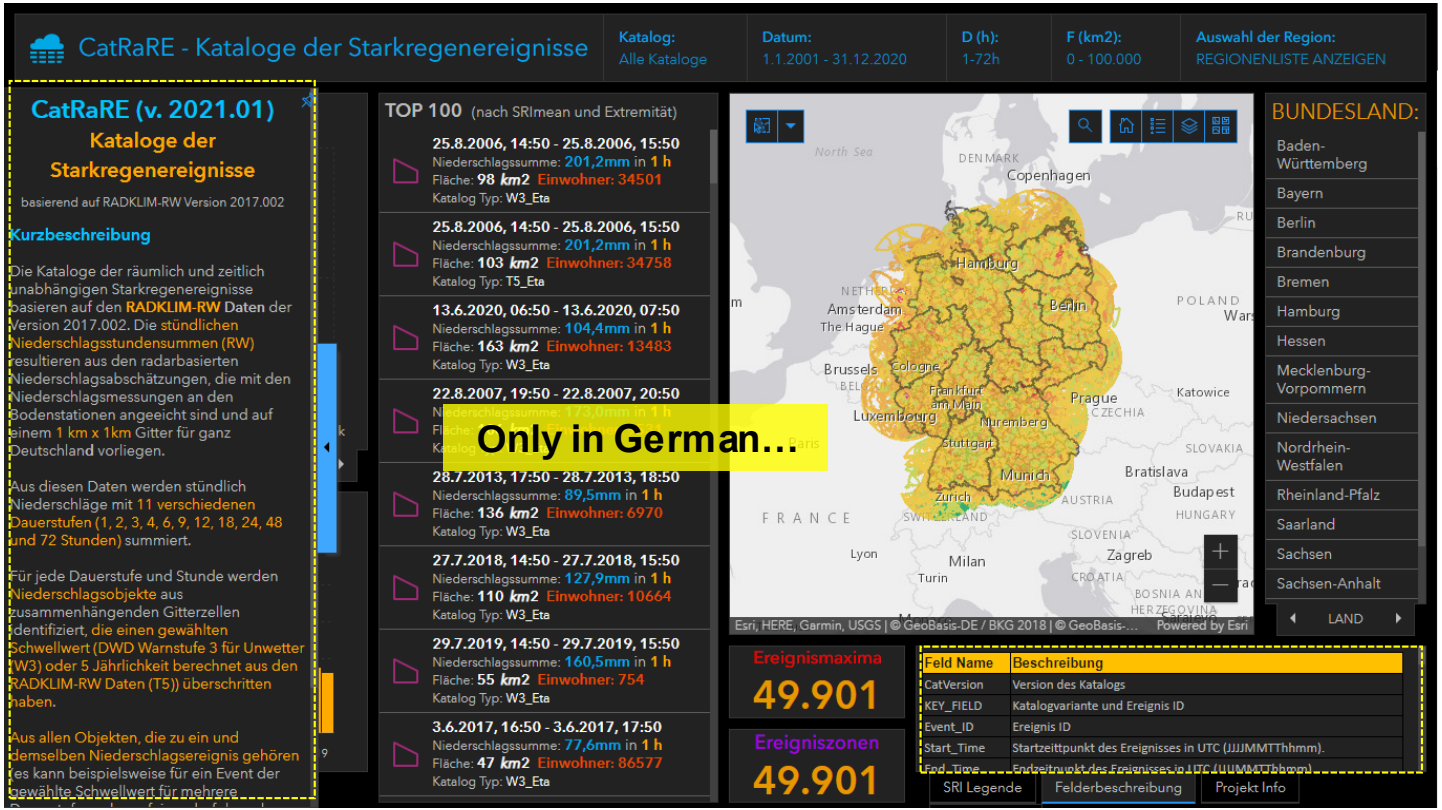
Wetter und Klima aus einer Hand



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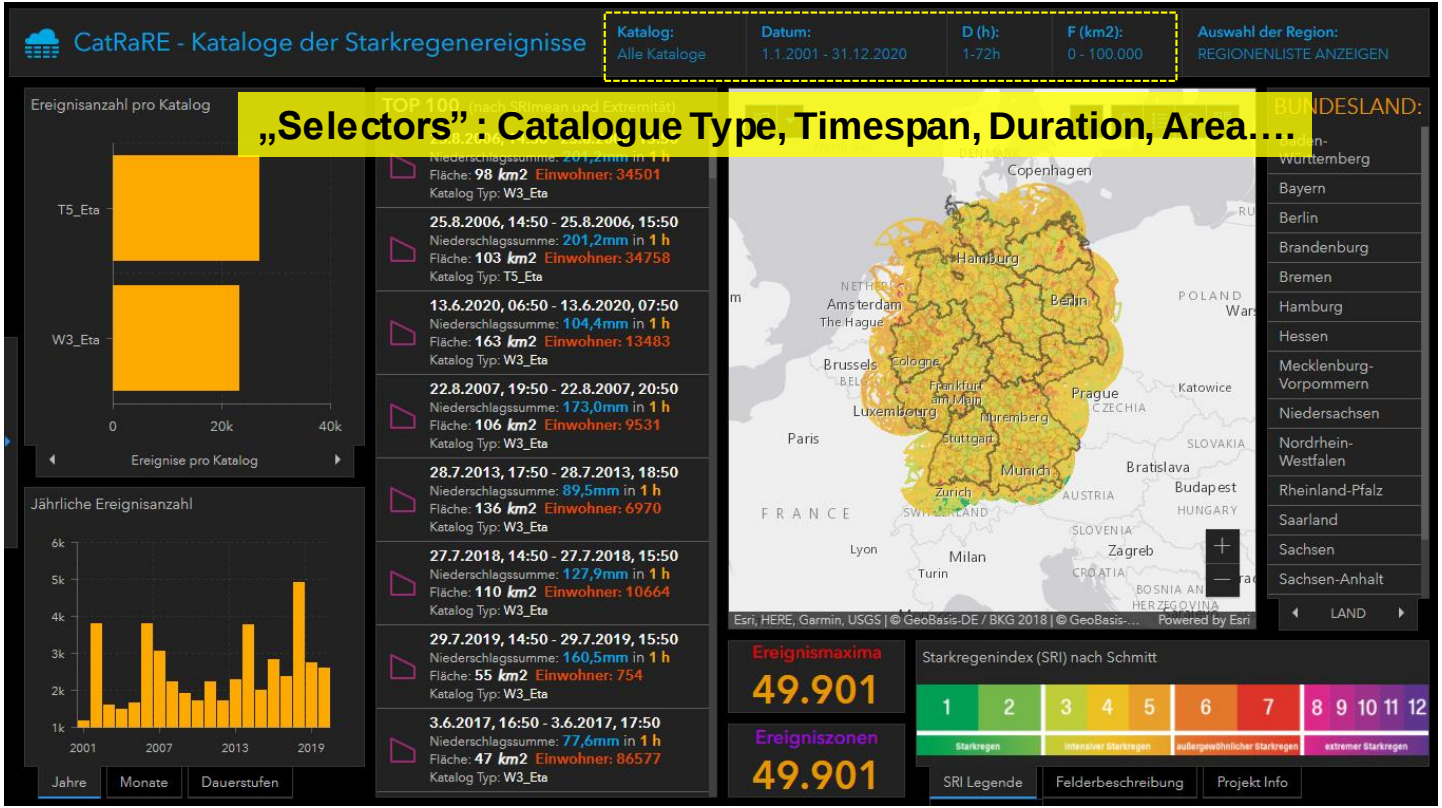
Wetter und Klima aus einer Hand



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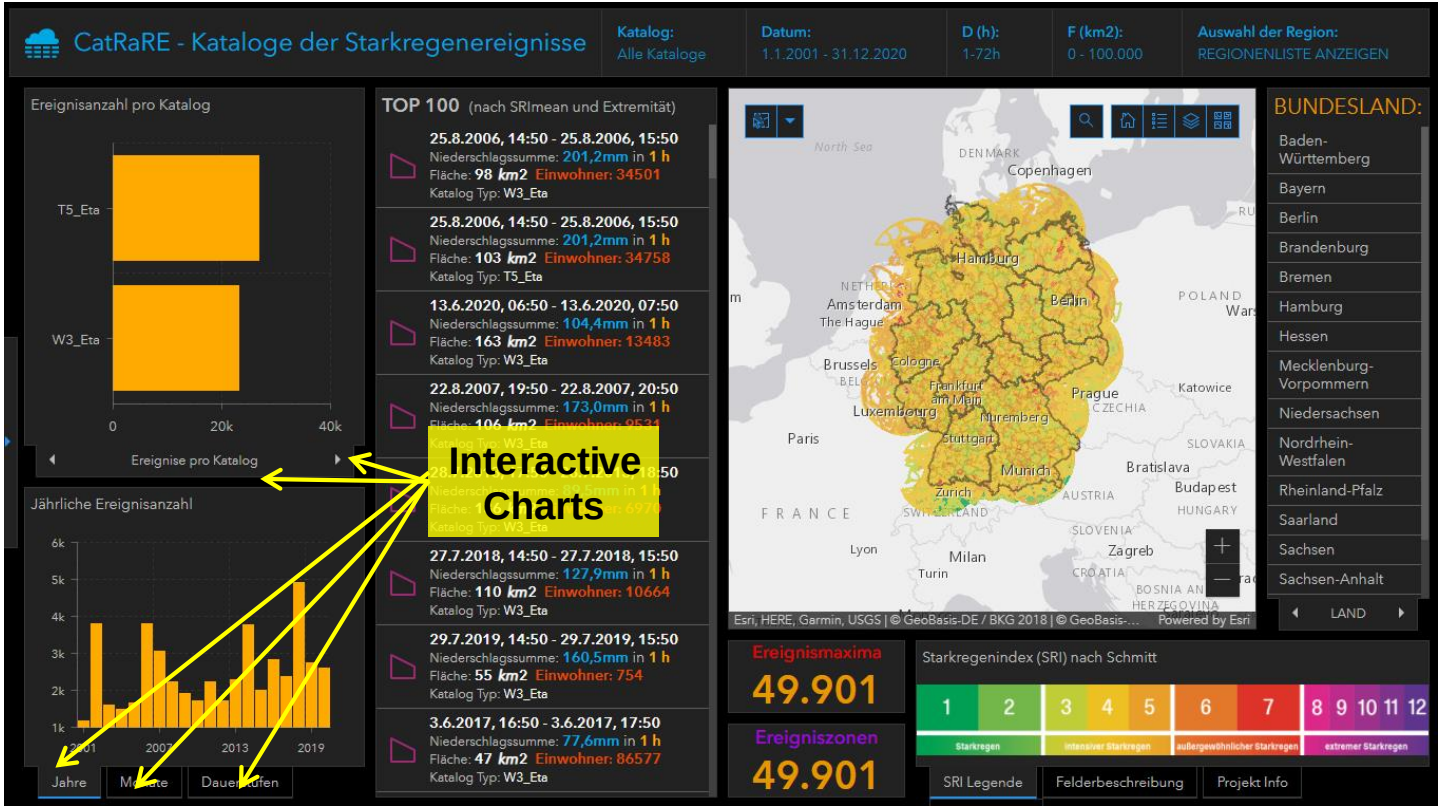
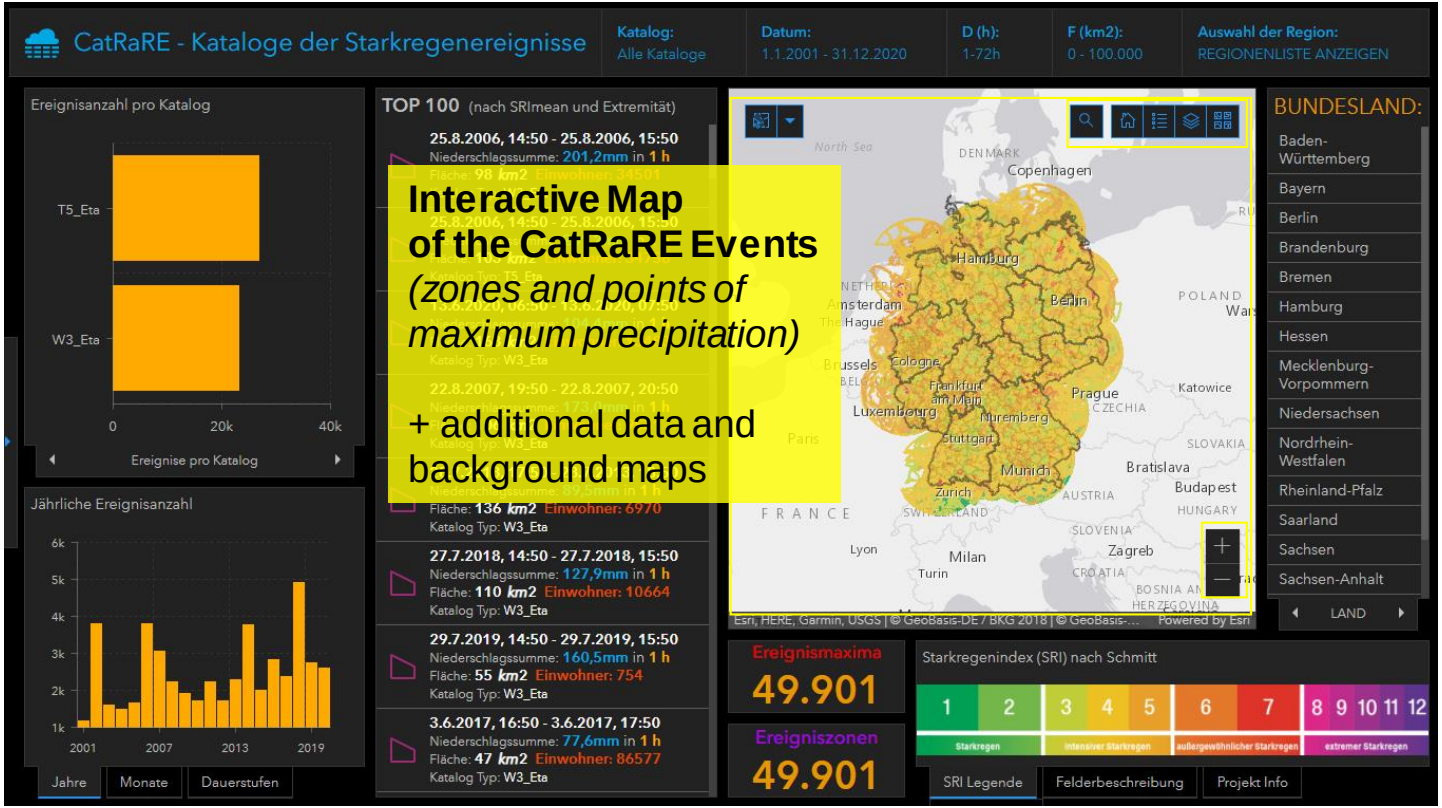
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



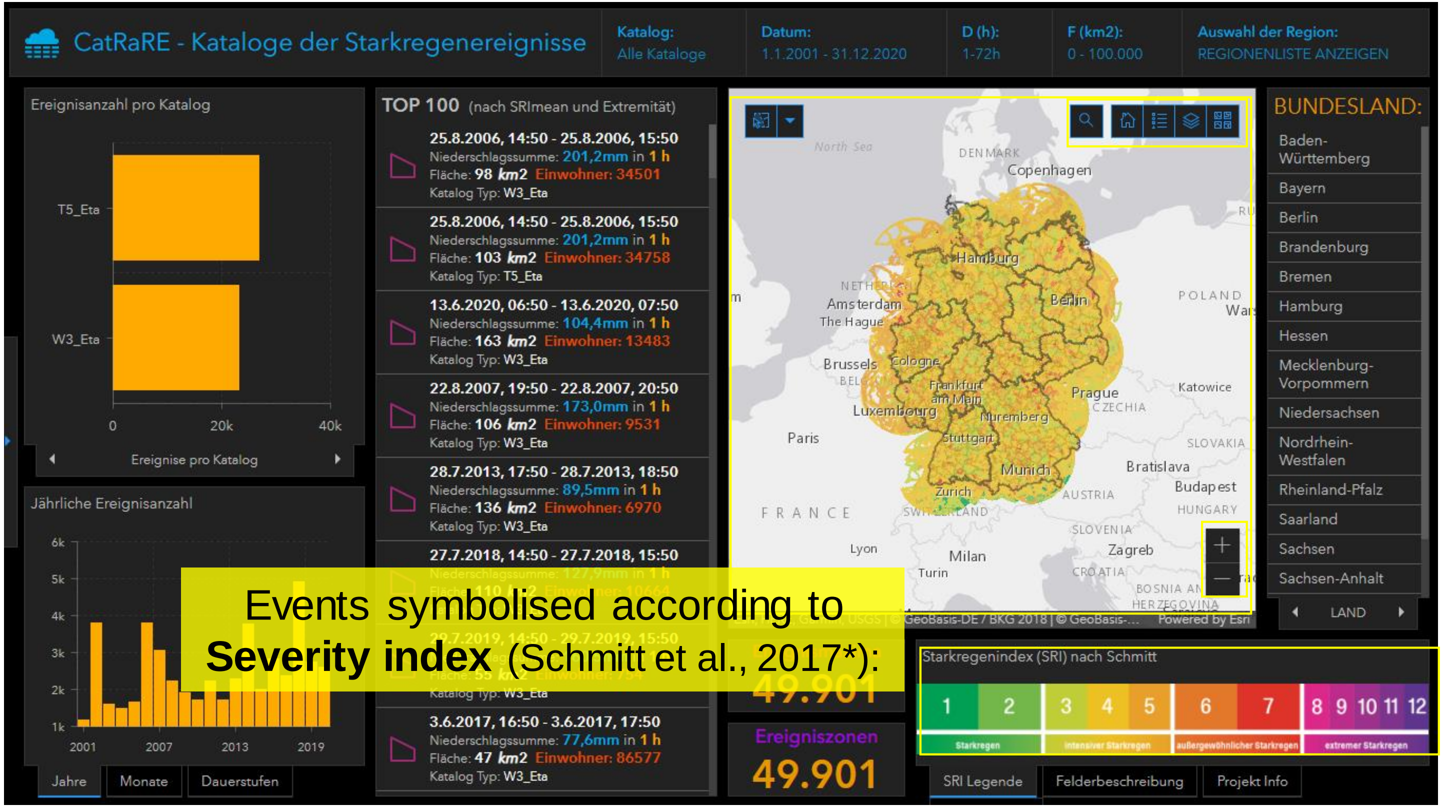
2 CatRaRE Dashboard (online)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



2 CatRaRE Dashboard (online)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

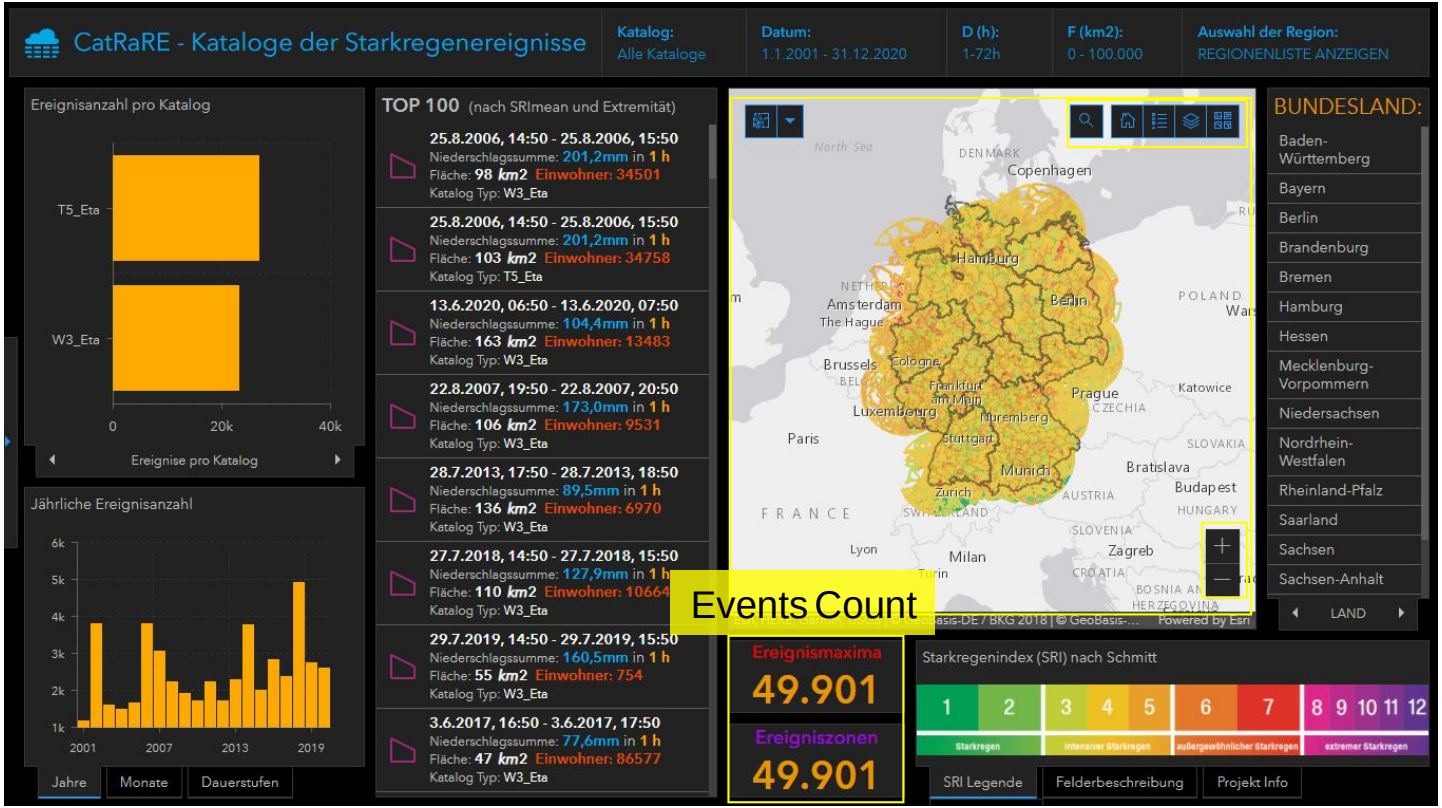


Events symbolised according to **Severity index** (Schmitt et al., 2017*):

*Schmitt, T.G.: Ortsbezogene Regenhöhen im Starkregenindexkonzept SRI12 zur Risikokommunikation in der kommunalen Überflutungsvorsorge, Korrespondenz Abwasser, Abfall, 2017 (64), Nr.4

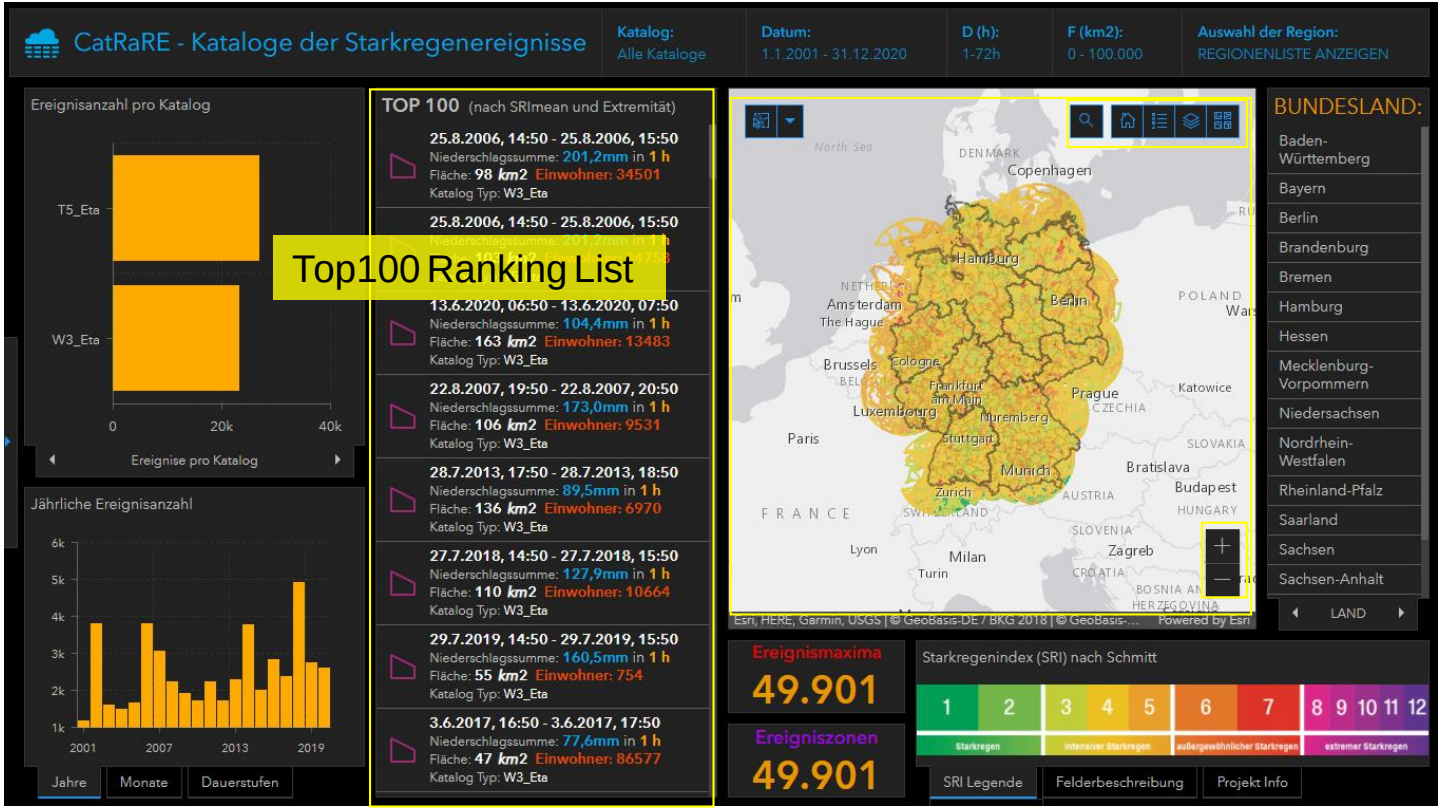
2 CatRaRE Dashboard (online)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



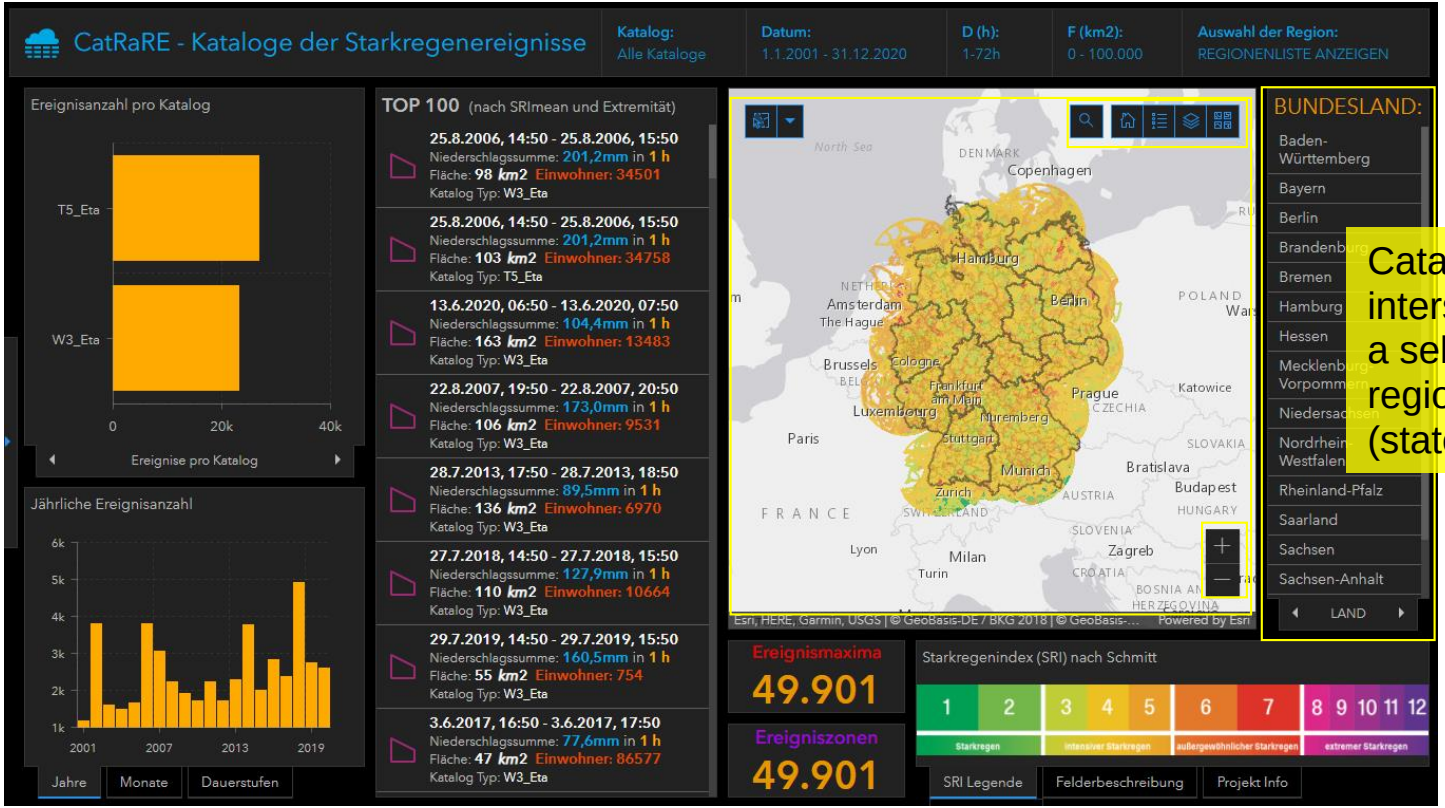
2 CatRaRE Dashboard (online)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



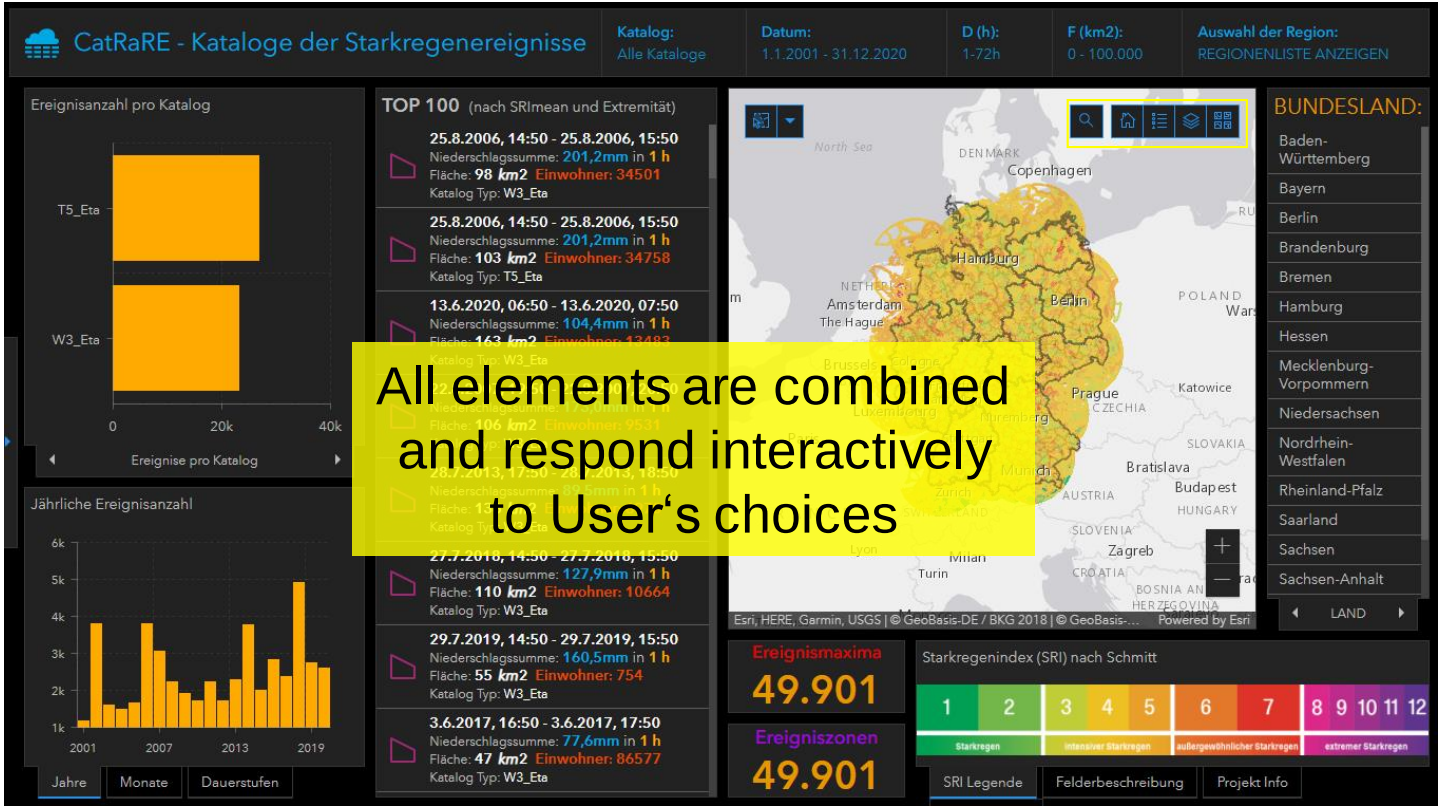
2 CatRaRE Dashboard (online)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Catalogues intersection with a selected region (state, county)

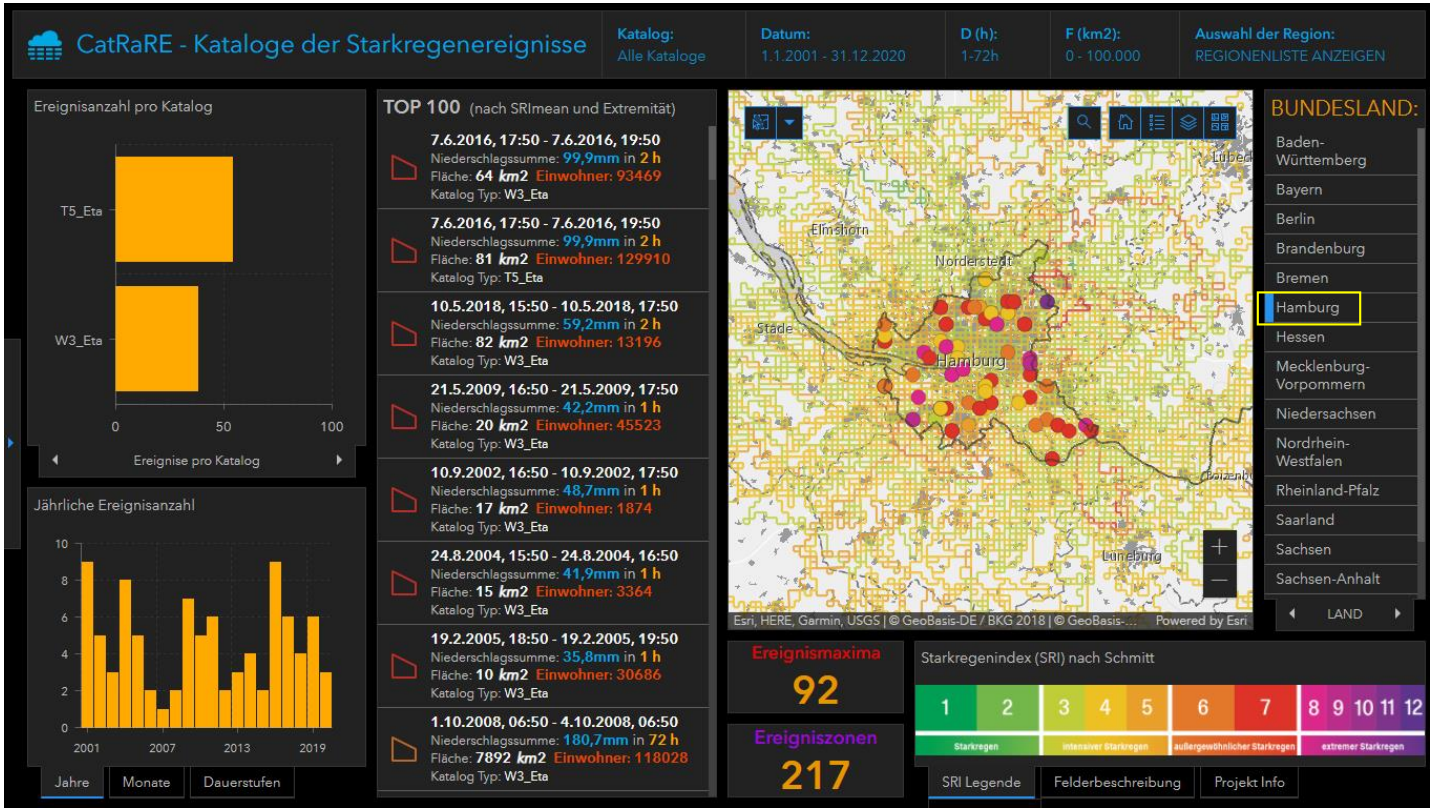
2 CatRaRE Dashboard (online)



All elements are combined and respond interactively to User's choices

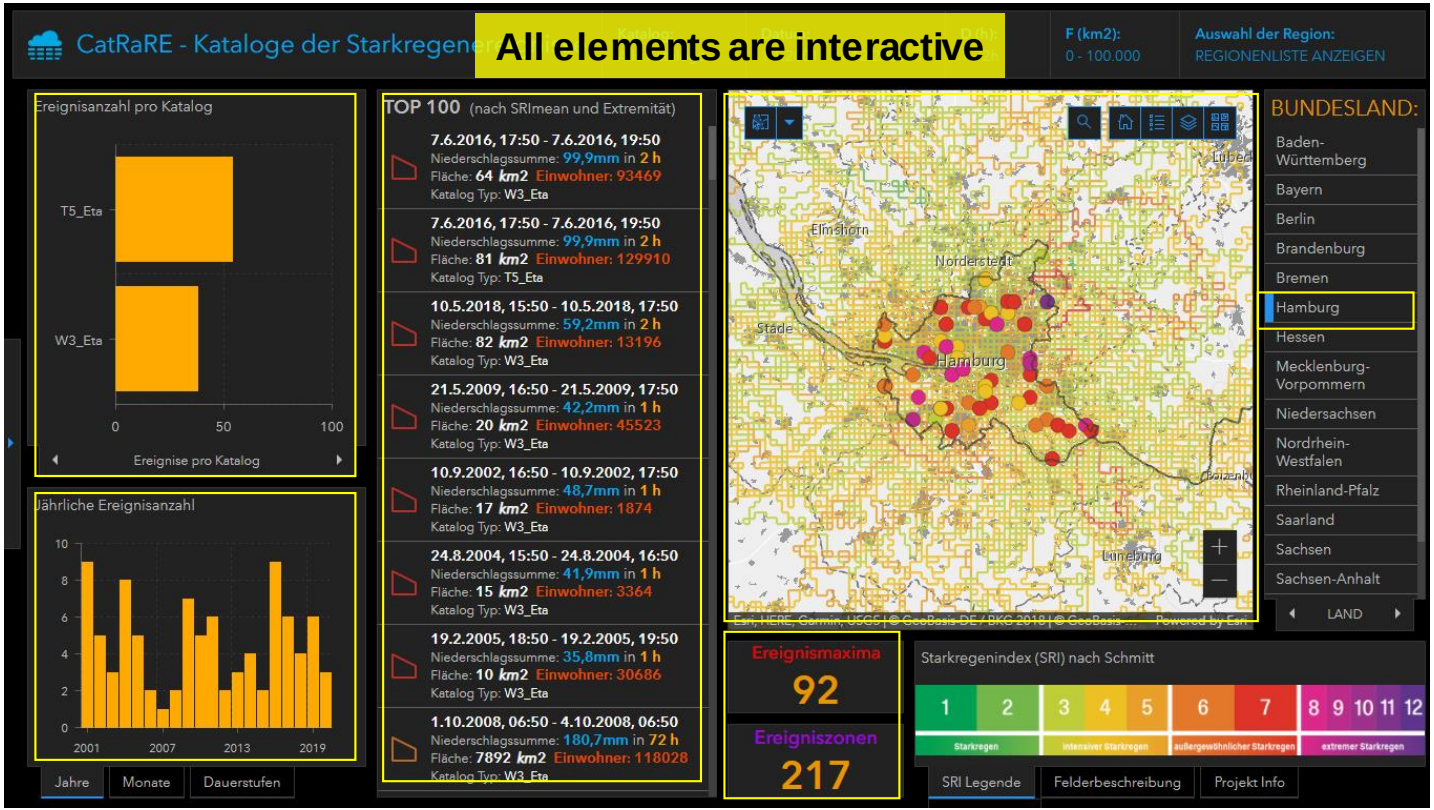
2 CatRaRE Dashboard (online)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



2 CatRaRE Dashboard (online)

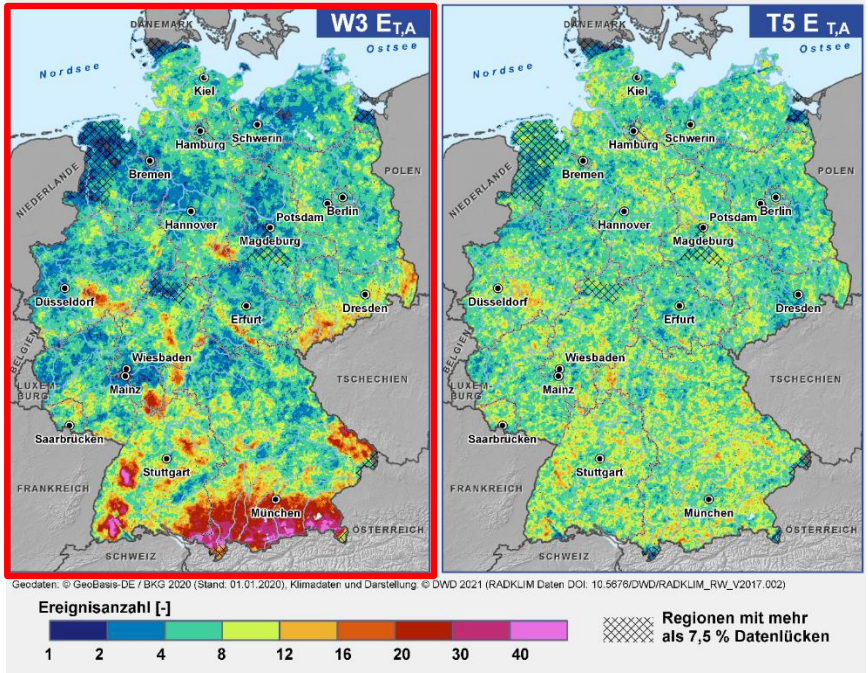
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Spatio-temporal patterns and extremity assessment of heavy rainfall events in Germany, derived from a radar-based catalogue (CatRaRE, 2001-2020)

1. Radar Climatology
2. Catalogue of extreme precipitation events
3. Spatio-temporal patterns
4. Applications of the CatRaRE Catalogue

Comparison between W3_$E_{T,A}$ and T5_$E_{T,A}$ catalogues



- The distribution of events according to Warning Level 3 threshold (**W3_$E_{T,A}$**) reflects the **orographic amplification** and can be treated more as a **"climatology pattern"**
- The events classified on the basis of the 5a-return period (**T5_ET,A**) are as expected more **evenly distributed**

Both catalogues have their users and applications.

On the following slides we present results based on the CatRaRE W3_$E_{T,A}$

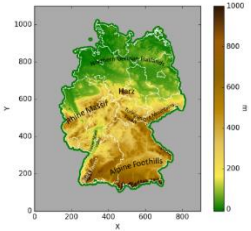
3 Spatio-temporal patterns

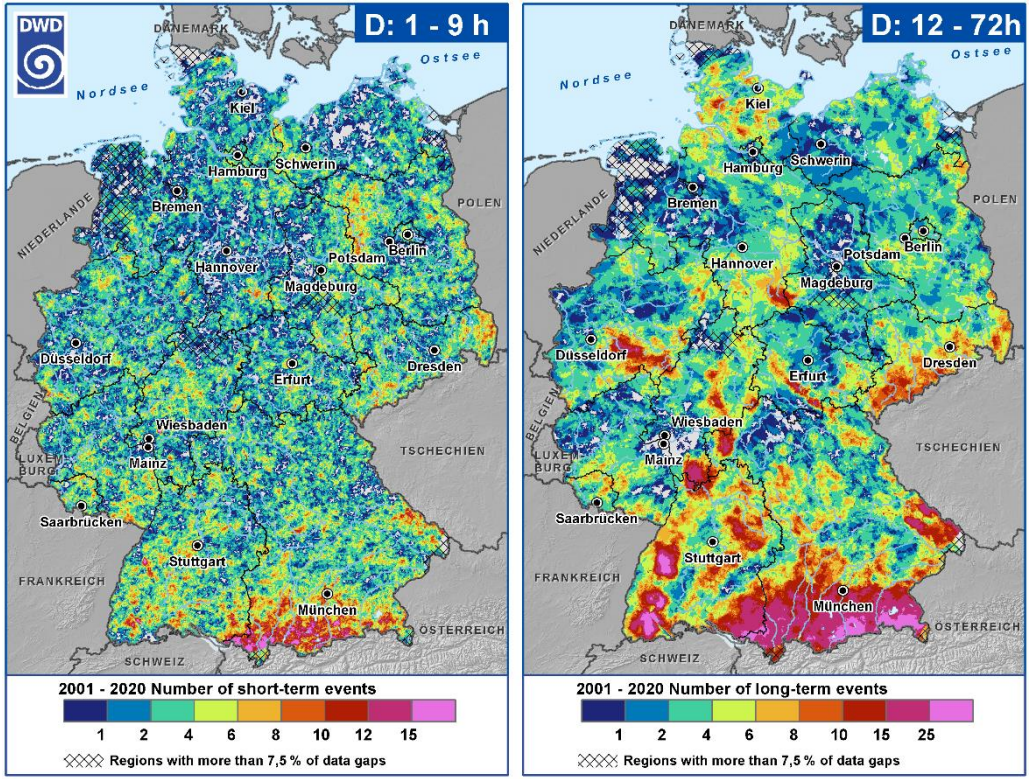
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Spatial distribution shows clear differences between long-lasting and short-term heavy precipitation events

- **Short-term** events (D = 1 to 9 h) are more **randomly distributed** over Germany

- Mostly **long-lasting** events (D = 12 to 72 h) are bound to **orography**





Data source and credits: © DWD 2021 (CatRaRE: 10.5676/DWD/CatRaRE_W3_Eta_v2021.01); Geodata: © GeoBasis-DE/BKG 2020 (Stand: 01.01.2020).

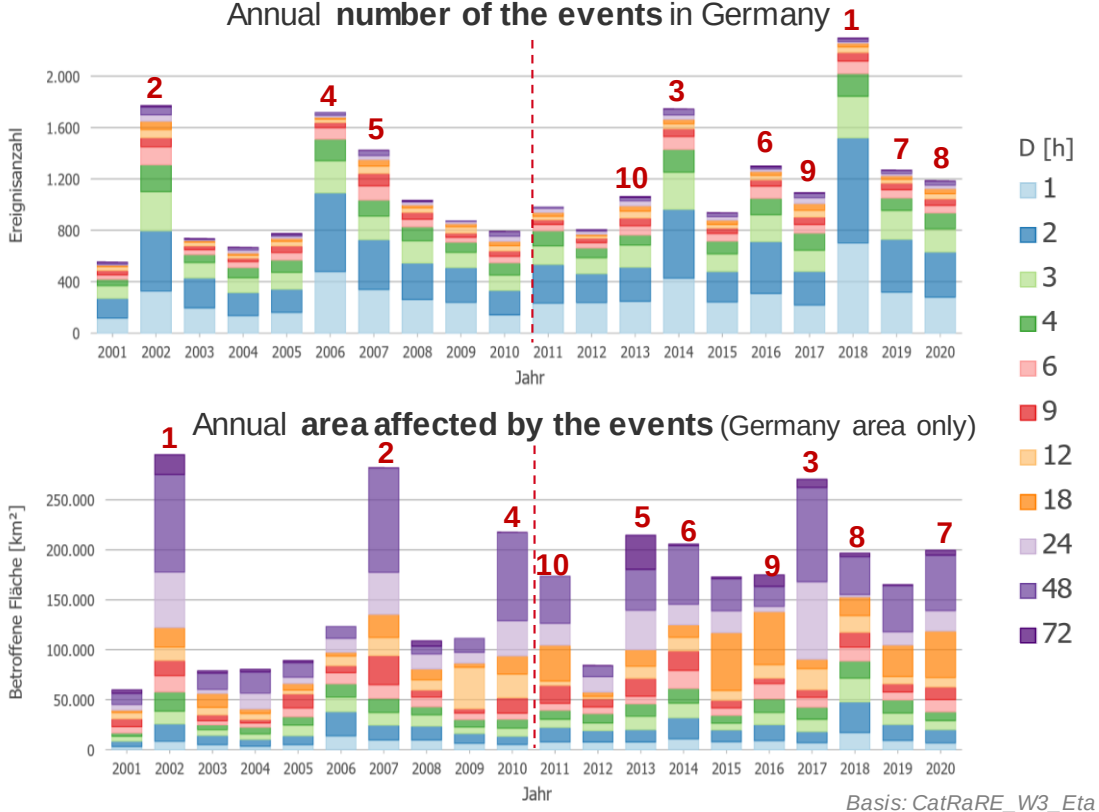
3 Spatio-temporal patterns

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Annual statistics of heavy- rainfall events:

- ➔ Large **interannual variability** of extreme precipitation events in Germany
- ➔ **Large areas** are mainly hit by events of **long durations** *(violett colors)*
- ➔ **Number** of extreme events is dominated by **short durations** *(blue colors)*
- ➔ Extremely dry year 2018 with largest number of extreme events (???)

More events and larger affected area in 2011-2020…but still not enough data for trend-analysis

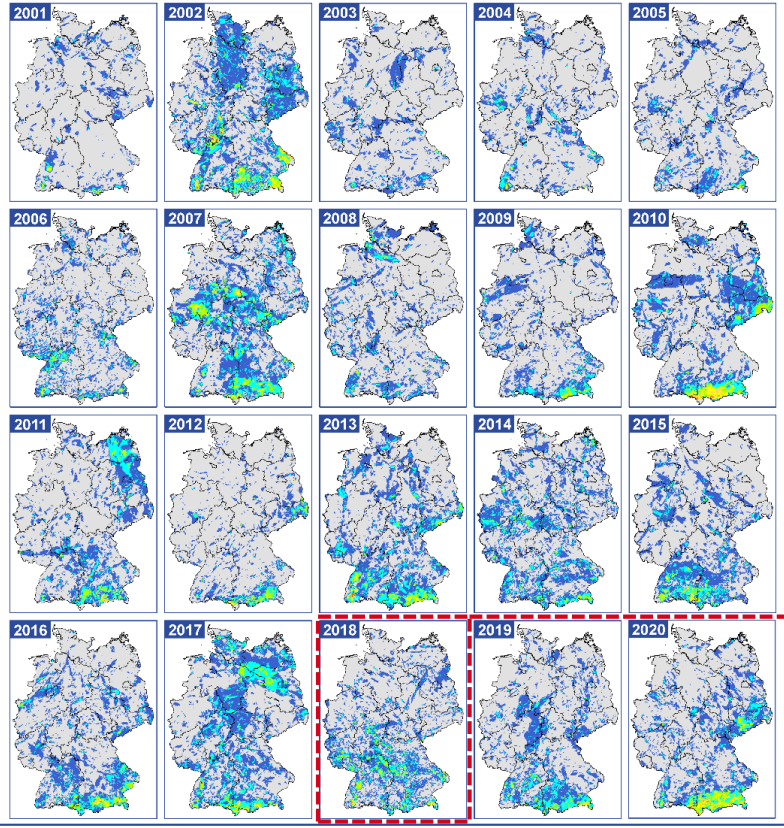


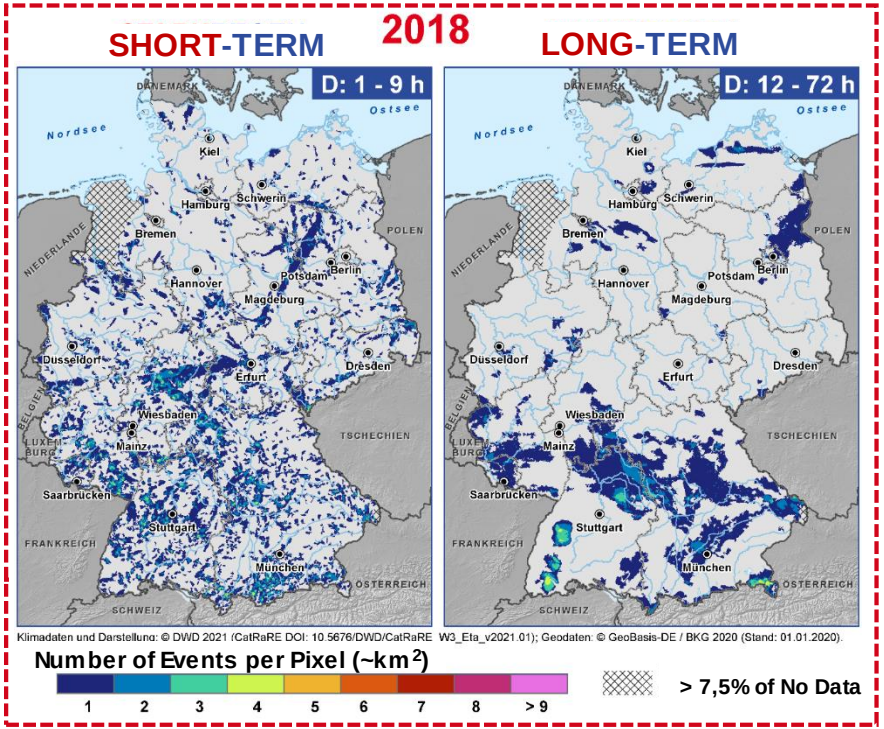
Basis: CatRaRE_W3_Eta

3 Spatio-temporal patterns

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Annual Number of heavy precipitation events

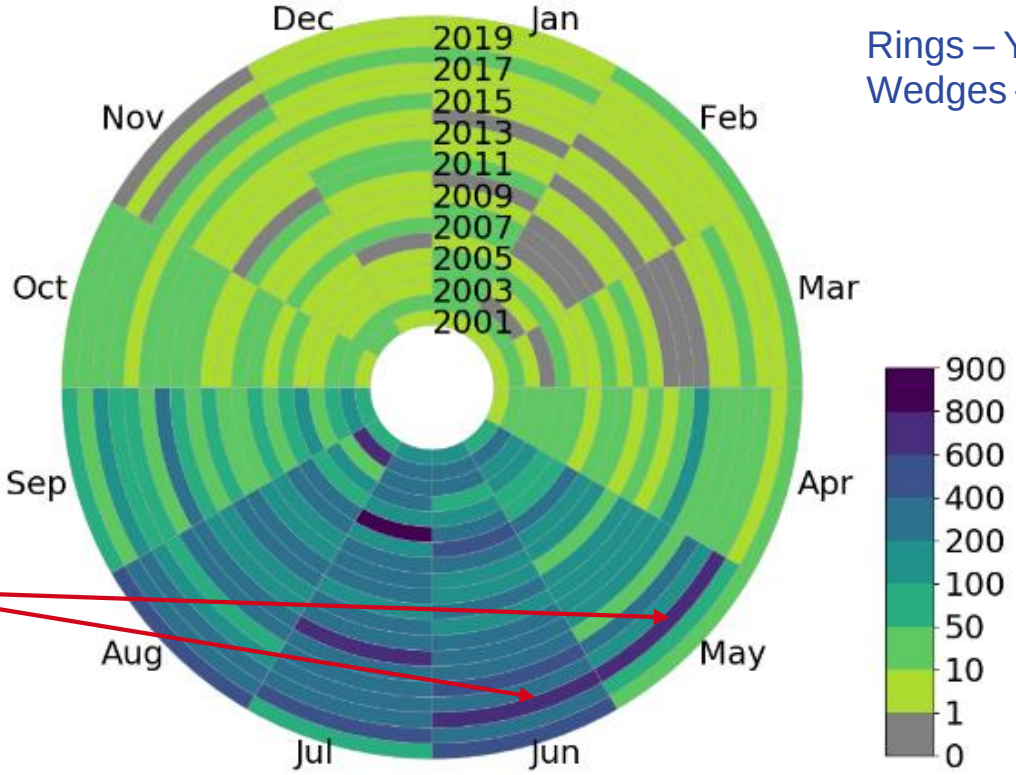




Basis: CatRaRE_W3_Eta

Monthly Number of Events ≥ Warning Level 3

(D: 1-72h, CatRaRE W3ETA)



Rings – Years
Wedges - Months

2018:
May – June

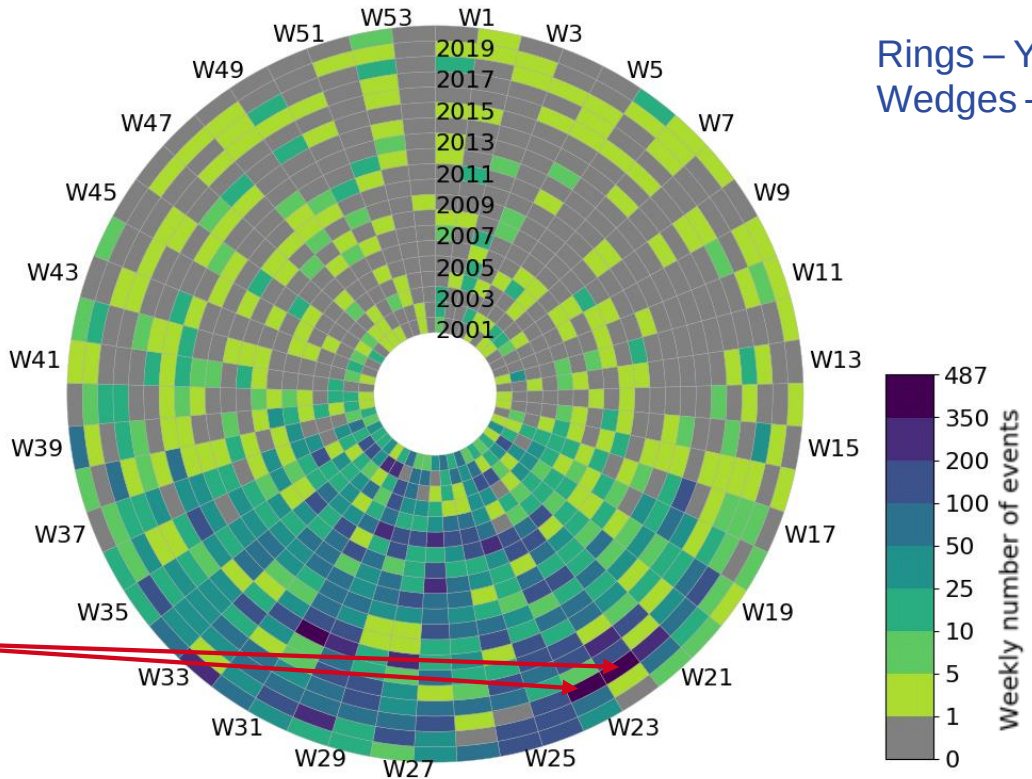
Basis: CatRaRE_W3_Eta

3 Spatio-temporal patterns

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Weekly Number of Events ≥ Warning Level 3

(D: 1-72h, CatRaRE W3ETA)



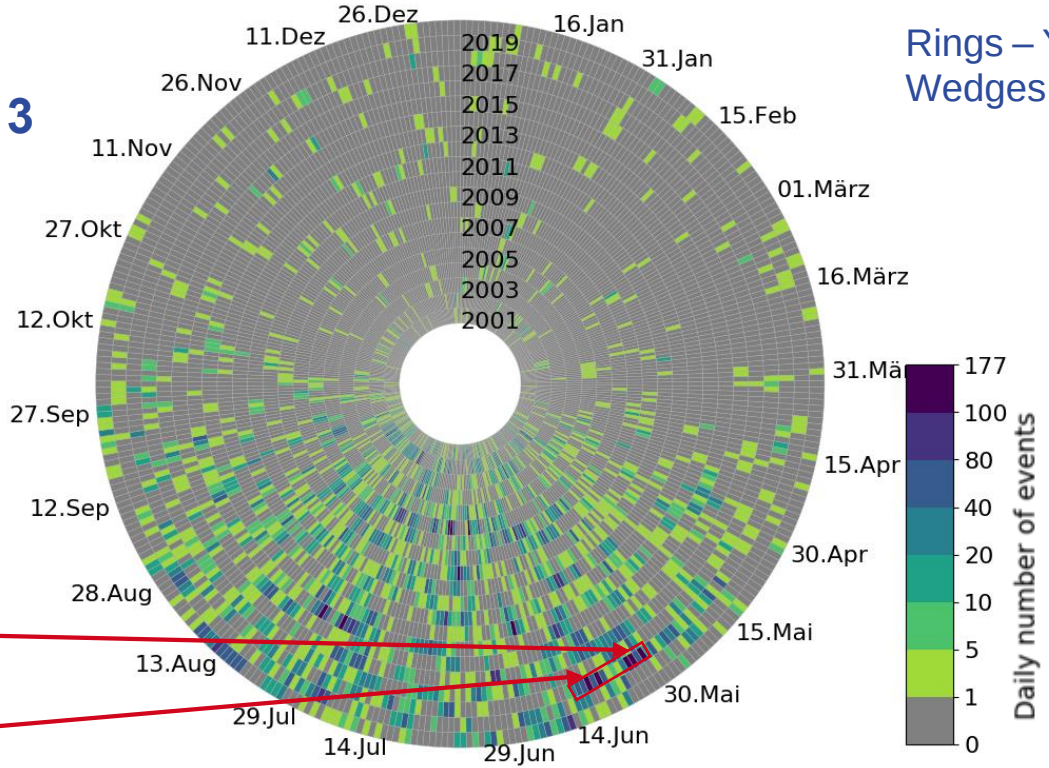
Rings – Years
Wedges - Weeks

Two weeks:
28.05.2018
- 11.06.2018

Basis: CatRaRE_W3_Eta

Daily Number of Events ≥ Warning Level 3

(D: 1-72h, CatRaRE W3ETA)



Single "record days":

29.05.2018: 117
31.05.2018: 136
01.06.2018: 119
09.06.2018: 177

Basis: CatRaRE_W3_Eta

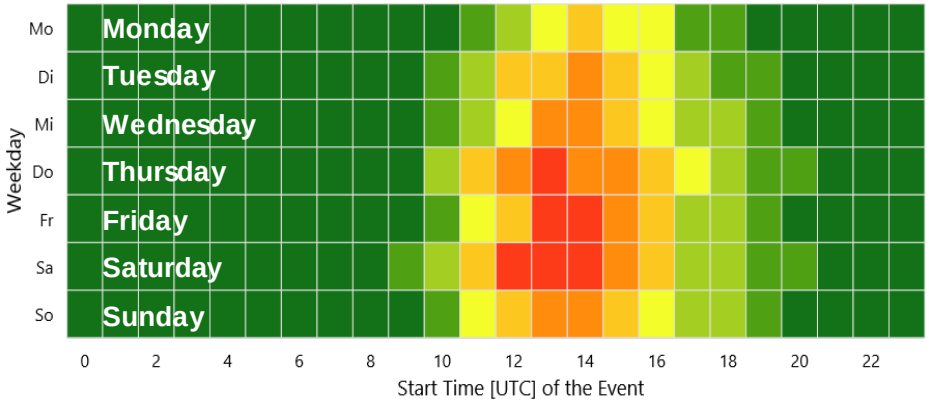
3 Spatio-temporal patterns

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Variation during the day and the week (based on the Start-time of the Event)

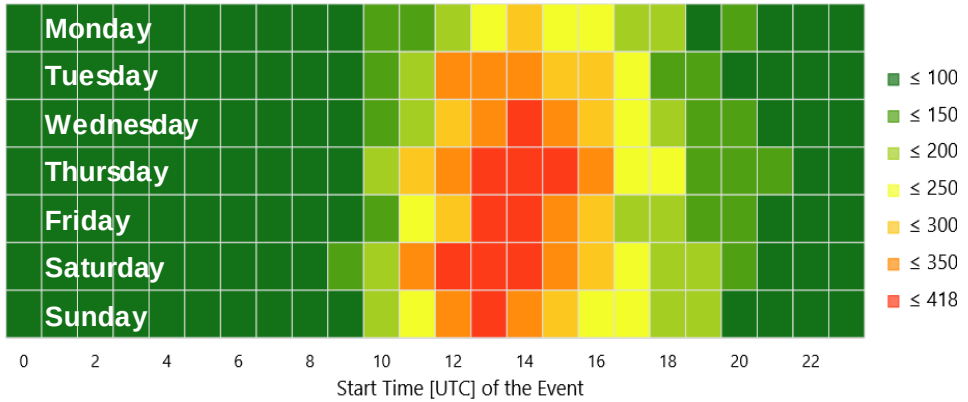
Short-term Events

Number of Events (D: 1 - 9 h) (W3_ETA, 2001 - 2020)



All Events

Number of Events (D: 1 - 72 h) (W3_ETA, 2001 - 2020)



- ➔ accumulation of events in the **afternoon and early evening** when typically **summer convection** occurs
- ➔ **smaller number of events at the begining of the week** and delayed convection beginning on Monday
  - ➔ **coincidental finding or – derived from the weekly cycle of ozone pollution = traffic volume?**
    – more detailed analysis is needed…

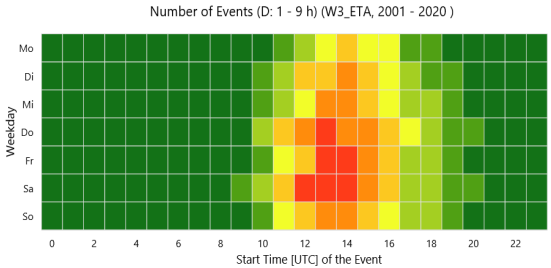
Spatio-temporal patterns and extremity assessment of heavy rainfall events in Germany, derived from a radar-based catalogue (CatRaRE, 2001-2020)

1. Radar Climatology
2. Catalogue of extreme precipitation events
3. Spatio-temporal patterns
4. Applications of the CatRaRE Catalogue

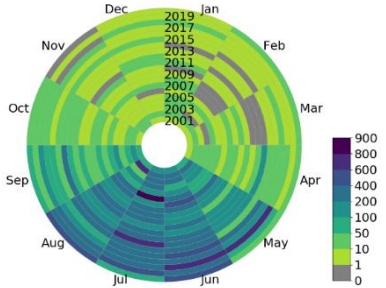
4 Applications of the CatRaRE Catalogue

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

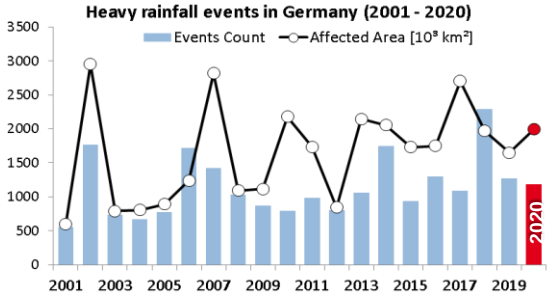
TIME



Hour, Day



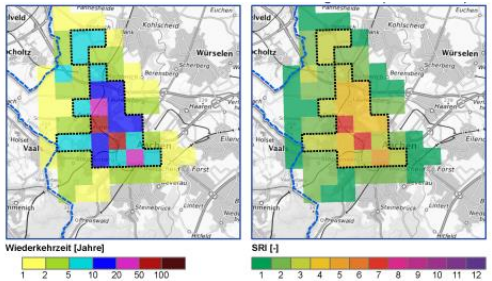
Weeks, Months



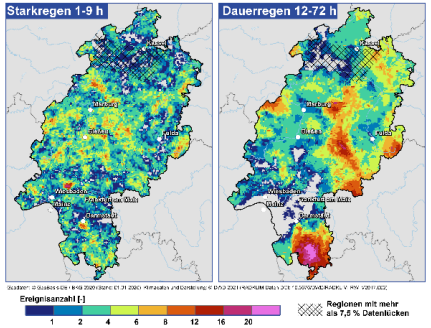
Year, Years

SPACE

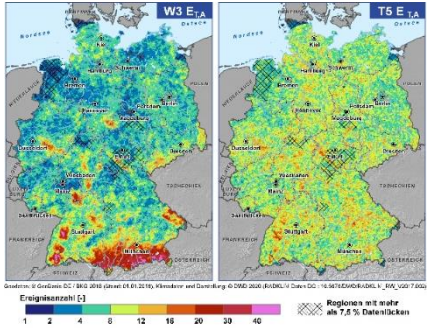
Single events



Regional variability



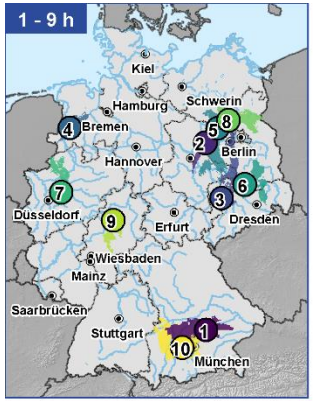
Country-wide

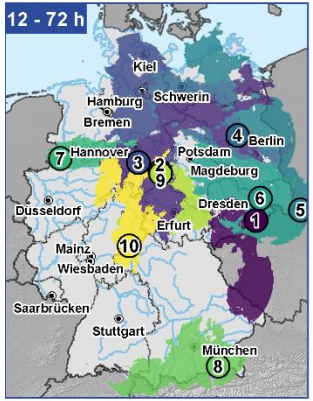


4 Applications of the CatRaRE Catalogue

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Ranking of extreme precipitation events





EXAMPLE:

Top10 short-term *(upper)* and long-term *(bottom)* events in 2001-2020

Starkregenereignisse (1 - 9 Std.)

RANK	Date_START	D_Std	Area	Eta	RRmax	RRmean	SRImax	SRImean	BDL/LKS/GMD_RRmax
1	21.07.2014 15:50	6	5360	53.2	74.2	45.61	8	4	BY /Freising /Wang
2	01.08.2018 21:50	9	2649	51.2	155.3	63.65	11	5	ST /Jerichower Land /Genthin
3	11.06.2019 17:50	4	3231	49.4	216.1	46.74	12	5	SN /Leipzig /Parthenstein
4	23.06.2016 17:50	6	1501	47.7	166	61.83	11	6	NI /Emsland /Groß Berßen
5	21.07.2007 23:50	9	5289	45.9	105.4	48.58	8	4	BB /Havelland /Wiesenaue
6	05.07.2012 13:50	6	2775	44.6	140.6	50.18	10	5	BB /Elbe-Elster /Bad Liebenwerda
7	20.06.2013 10:50	3	2460	44.1	99.6	41.38	10	5	NW /Bochum /Bochum
8	13.06.2020 10:50	9	2937	43.8	150.8	53.88	11	5	BB /Ostprignitz-Ruppin /Rüthnick
9	30.05.2008 16:50	2	2154	41.5	97.6	42.38	10	5	HE /Marburg-Biedenkopf /Kirchhain
10	18.05.2002 16:50	9	6159	41.2	184.3	50.28	11	3	BY /Fürstenfeldbruck /Landsberied

Dauerregenereignisse (12 - 72 Std.)

RANK	Date_START	D_Std	Area	Eta	RRmax	RRmean	SRImax	SRImean	BDL/LKS/GMD_RRmax
1	12.08.2002 02:50	24	48420	208	283.1	86.89	11	5	SN /Sächsische Schweiz-Osterzgebirge /Altenberg
2	24.07.2017 07:50	48	54898	189	255.8	85.04	9	5	NI /Goslar /Bad Harzburg
3	17.07.2002 01:50	48	45053	176	187.2	85.26	10	5	NI /Hildesheim /Sibbesse
4	29.06.2017 10:50	24	33927	166	161.9	71.62	9	5	BE /Berlin /Berlin
5	21.07.2011 05:50	48	37879	145	187.2	82.44	8	5	Tschechien
6	25.09.2010 21:50	48	45655	133	154.5	79.38	8	4	SN /Bautzen /Wachau
7	26.08.2010 04:50	24	14519	132	163.9	86.16	10	6	NW /Borken /Schöppingen
8	30.05.2013 17:50	72	32937	127	319.5	131.95	8	4	BY /Rosenheim /Aschau i. Chiemgau
9	27.09.2007 12:50	48	26330	114	189.5	78.56	8	4	ST /Harz /Wernigerode
10	20.05.2019 12:50	18	22325	110	106.7	60.21	9	5	HE /Main-Kinzig-Kreis /Steinau an der Straße

Basis: CatRaRE_W3_Eta

4 Applications of the CatRaRE Catalogue

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Event Case Studies

EXAMPLE:

Extremely heavy rainfall event over the city of Münster on 28th July 2014

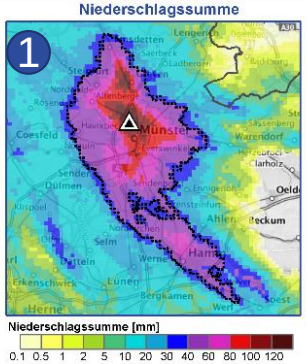
Starkregen in Münster am 28. Juli 2014 - Ereignisfallstudium

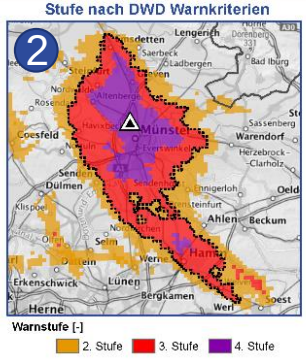
Area and Location

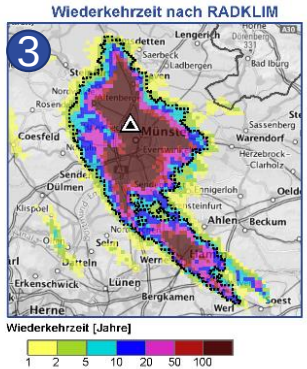
Start Time:		28.07.2014 13:50:00
Dauerstufe:		9 h
Fläche:		1213 km²
RRmax / RRmean:	175.8 mm /	62.29 mm
SRImax / SRImean:	11 /	6
Tmax / Tmean:	>> 100 Jahre /	71 Jahre
Eta:		36.33

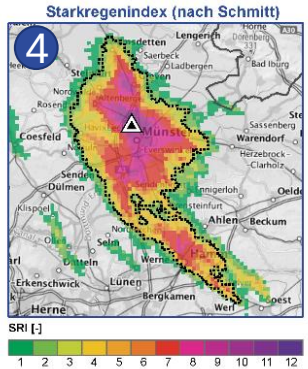
Main Attributes

Bundesland:	Nordrhein-Westfalen
Landkreis:	Münster
Gemeinde:	Münster
Einwohnerzahl:	594443
Bebaute Fläche:	6.3 %
Versiegelte Fläche:	8.2 %
Minimale Höhe über Meeresniveau:	26 m
Maximale Höhe über Meeresniveau:	197 m
Wetterlage:	SOZAF
21d-Vorregenindex: (Max / Mean)	17 / 9.4 mm









FELDERBESCHREIBUNG:
Start Time - Anfangszeitpunkt des Ereignisses in UTC (TT.MM.JJJJ hh:mm); Duration - Signifikante Dauerstufe [h] des Ereignisses; Area - Gesamtfläche [km²] des Ereignisses (nach RADOLAN Projektion); RRmax/RRmean - Maximaler/Mittlerer Niederschlag [mm]; SRImax/SRImean - Maximaler/Mittlerer Starkregenindex nach Schmitt (Wertebereich [0,12]); Tmax/Tmean - Maximale/Mittlere Wiederkehrzeit nach RADKLIM Daten; Eta - Extremität.

1. **Precipitation sum**
2. **Areas where DWD's Warning Levels are exceeded,**
3. **Return period**
4. **Heavy Precipitation Index (SRI) according Schmitt**

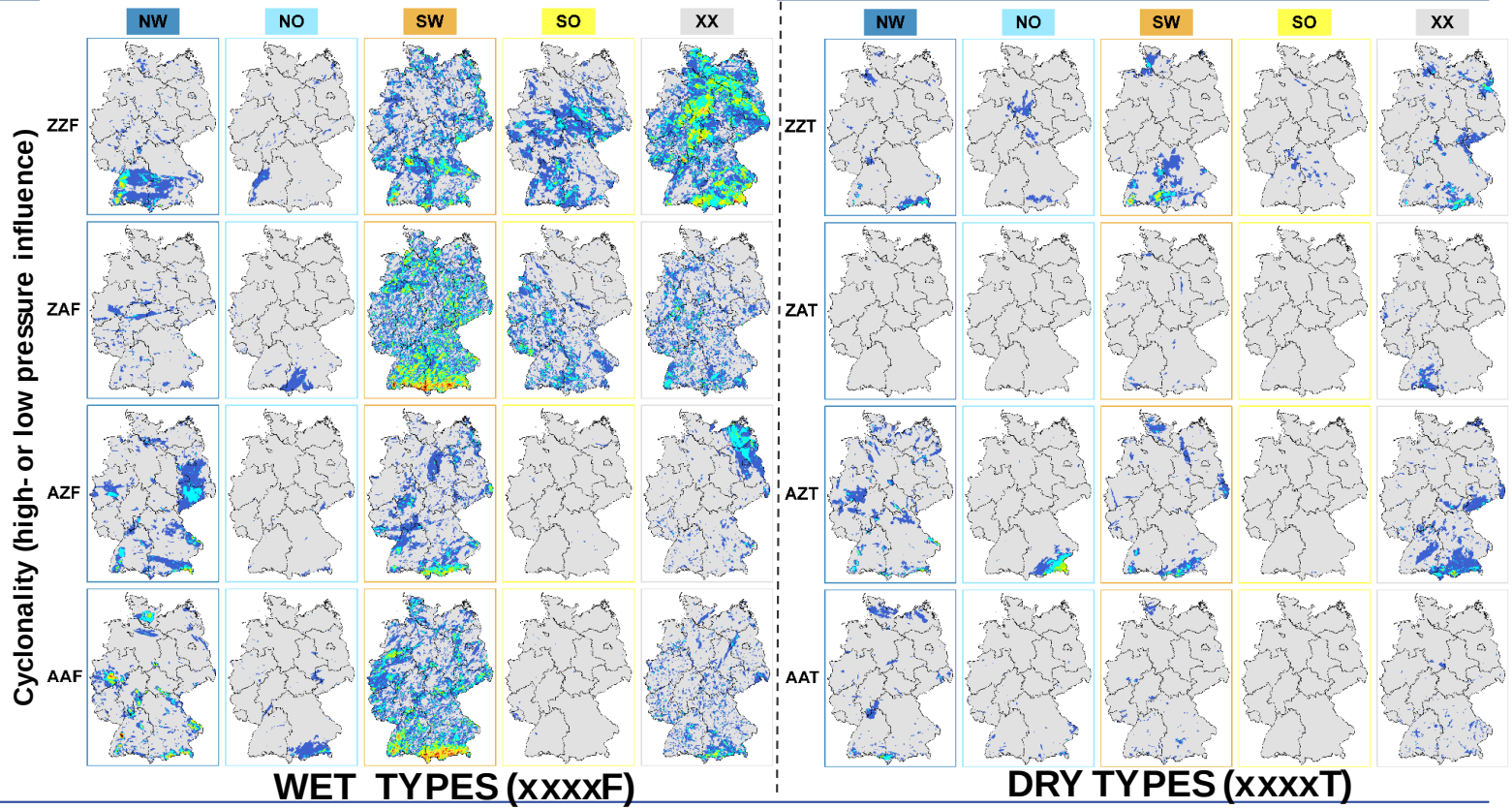
→ **Data basis for** all four elements **is the RADKLIM Dataset** (v. 2017.002)

4 Applications of the CatRaRE Catalogue

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Combining CatRaRE W3_$E_{T,A}$ with the DWD's Objective Weather Classification

2001-2020 number of heavy rainfall events per RADKLIM Pixel **depending on the weather type**



Basis: CatRaRE_W3_Eta

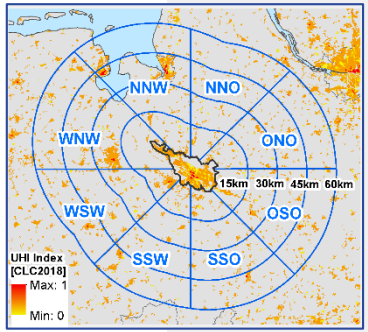
4 Applications of the CatRaRE Catalogue

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Combining CatRaRE W3_$E_{T,A}$ with the DWD's Objective Weather Classification

→ Does urbanization impact rainfall?
Hypothesis: rainfall increase in the downwind region of the city (up to 50 km)***

Relative area affected by heavy-rainfall events (1 - 9 h) depending on the advection type and the distance to the city of Bremen



"City-effect" analysis for Bremen
(lack of neighboring cities and orography influences but the North Sea…)

***Liu und Niyogi 2019, https://doi.org/10.1038/s41598-019-42494-2

4 Applications of the CatRaRE Catalogue

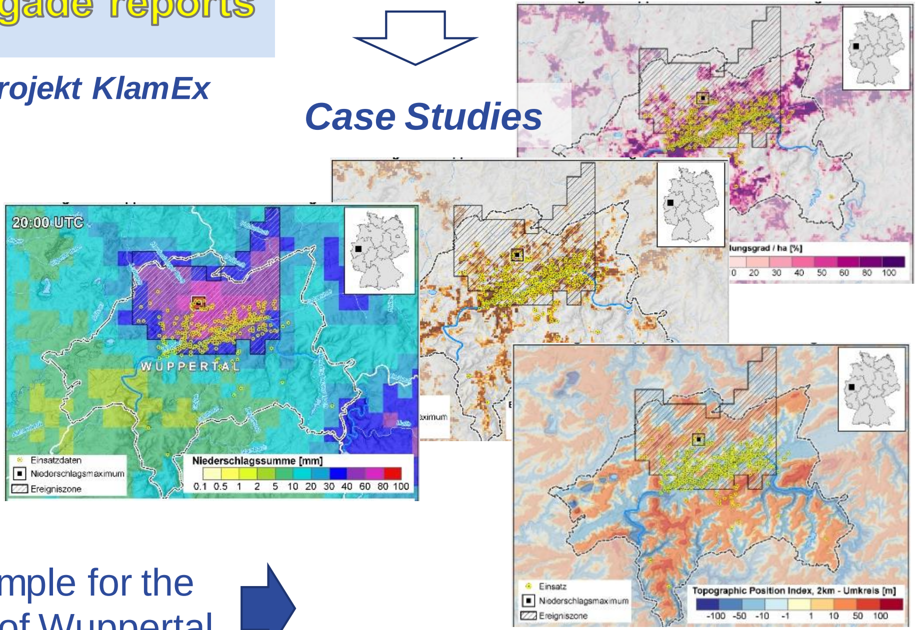
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Combining CatRaRE W3_$E_{T,A}$ with fire brigade reports

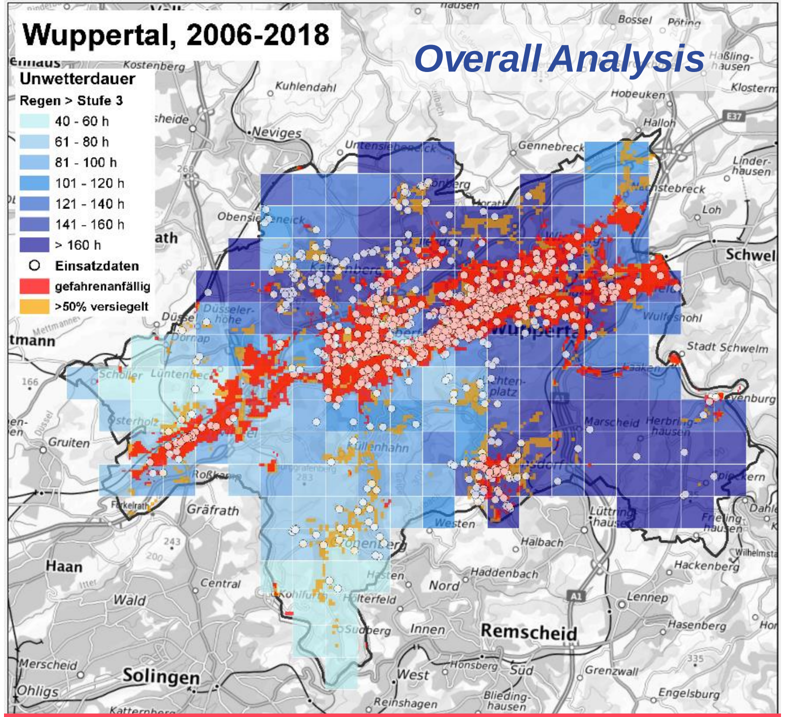
→ ***Projekt KlamEx***

Hot-spot analysis: combination of rainfall parameters and geographical variables *(sealing, settlement, topography…)*

Case Studies



Overall Analysis



Example for the city of Wuppertal

Hot-Spots: The fire brigade's operations are significantly more often in strongly sealed and densely settled sinks…
(RAINFALL ≠ RUNOFF)

Spatio-temporal patterns and extremity assessment of heavy rainfall events in Germany, derived from a radar-based catalogue (CatRaRE, 2001-2020)

SUMMARY

(+ References / Links)

Summary

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- We have created an objective ***Catalogue of Radar-based heavy Rainfall Events "CatRaRE"***, which contains all heavy short-term and long-term rain events in Germany from 2001 onwards
- The CatRaRE Catalogues were published on the **DWD's Opendata server**
  - We **provide our data in user-friendly format (.csv , Geodatabase, Online Dashboard)**
  - Like RADKLIM Dataset, the CatRaRE Catalog will be **updated annually** by the DWD
- Due to the **large number of attributes** (met / geo) and **possibility of further extensions** there are many options for interesting applications and analysis - for us and other users…
- Already conducted analyses show:
  - **extreme events of short durations happen everywhere in Germany** and depend less on orography than precipitation of low intensity and long durations **(so everybody can be affected!)**
  - large interannual variability of extreme precipitation events **but not enough data for trend analysis**
  - **also an extremely hot and dry year** (2018) **can bring an enormous number of extreme events**

Do you want to know more?

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

CatRaRE PAPER (ENG):
"CatRaRE: A Catalogue of Radar-based Heavy Rainfall Events in Germany Derived from 20 Years of Data"
by Katharina Lengfeld, Ewelina Walawender, Tanja Winterrath and Andreas Becker, Meteorol. Z. (Contrib. Atm. Sci.) PrePub Article, 2021 **(Link)**

CatRaRE: A Catalogue of radar-based heavy rainfall events in Germany derived from 20 years of data

Katharina Lengfeld*, Ewelina Walawender, Tanja Winterrath and Andreas Becker

Deutscher Wetterdienst, Frankfurter Straße 135, 63067 Offenbach am Main, Germany

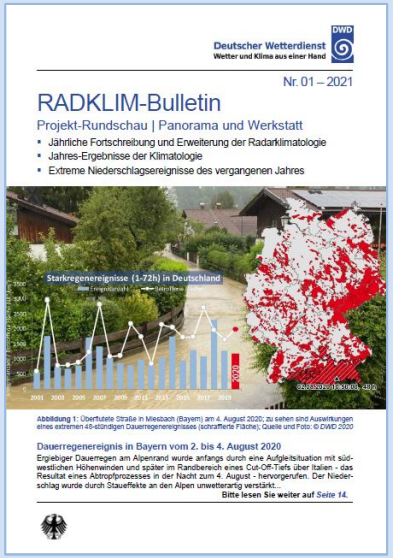
Abstract

1 Introduction

In German (click on the miniature to open the publication):

Klassifikation meteorologischer Extremereignisse zur Risikovorsorge gegenüber Starkregen für den Bevölkerungsschutz und die Stadtentwicklung (KlamEx)

Projekt der Strategischen Behördenallianz „Anpassung an den Klimawandel"



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Nr. 01 – 2021

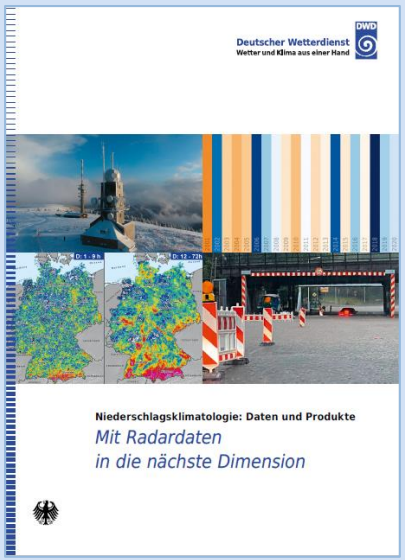
RADKLIM-Bulletin

Projekt-Rundschau | Panorama und Werkstatt

- Jährliche Fortschreibung und Erweiterung der Radarklimatologie
- Jahres-Ergebnisse der Klimatologie
- Extreme Niederschlagsereignisse des vergangenen Jahres

Starkregenereignisse (1-72h) in Deutschland

Dauerregenereignis in Bayern vom 2. bis 4. August 2020



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Niederschlagsklimatologie: Daten und Produkte

Mit Radardaten in die nächste Dimension

Easy way to find the CatRaRE Data

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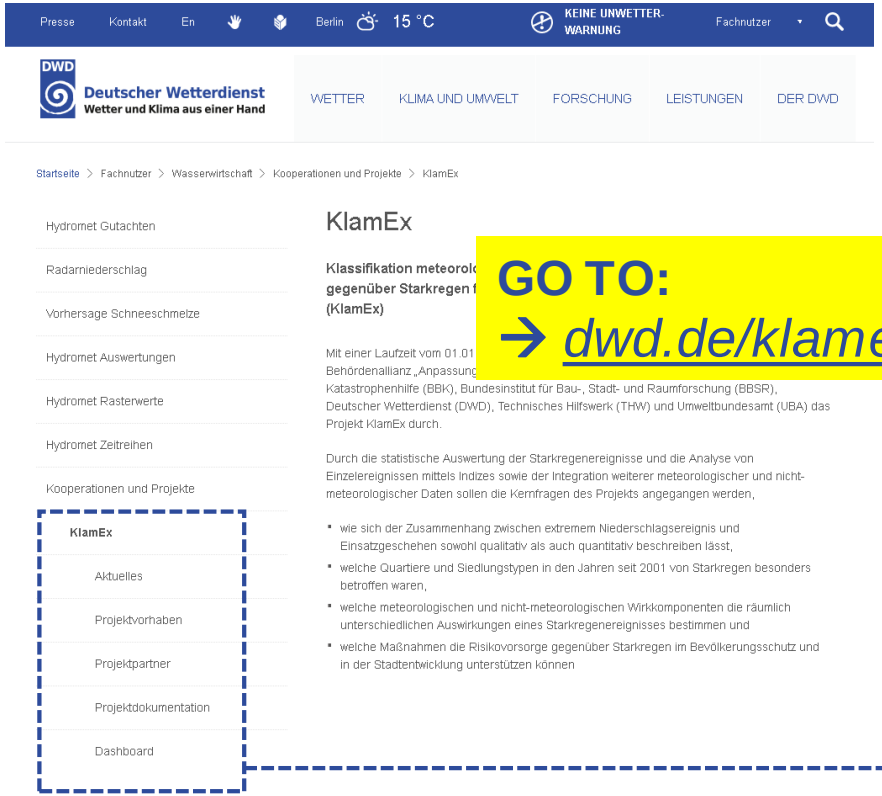
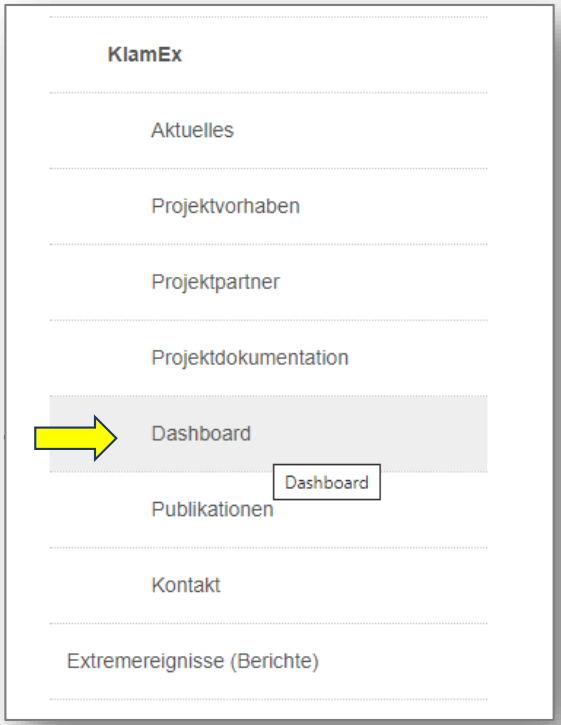
CatRaRE W3_Eta_2021.01:
DOI: *10.5676/DWD/CatRaRE_W3_Eta_v2021.01*
CatRaRE T5_Eta_2021.01 :
DOI: *10.5676/DWD/CatRaRE_T5_Eta_v2021.01*

Easy way to find the CatRaRE Dashboard

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



GO TO:
→ *dwd.de/klamex*



Thank You for your attention!

- CatRaRE Events Catalogues : https://www.dwd.de/catrare
- Radar Climatology Dataset - RADKLIM: https://www.dwd.de/radklim
- Project KlamEx (inludes the Dashboard): https://www.dwd.de/klamex

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E-Mail: hydromet@dwd.de

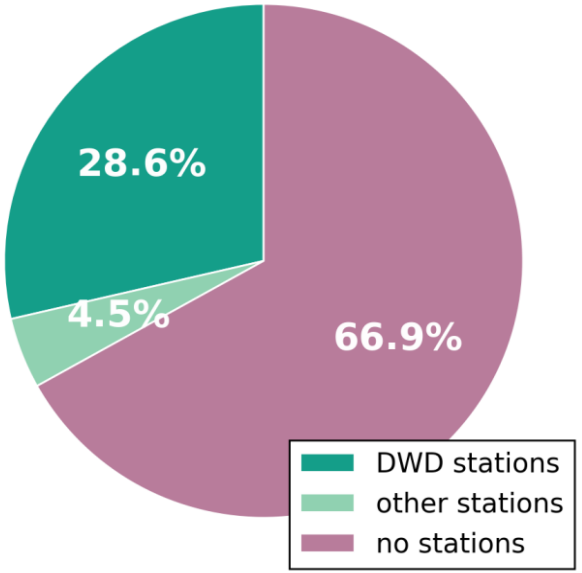
ADDITIONAL MATERIALS

Motivation: The benefit of area-covering measurements

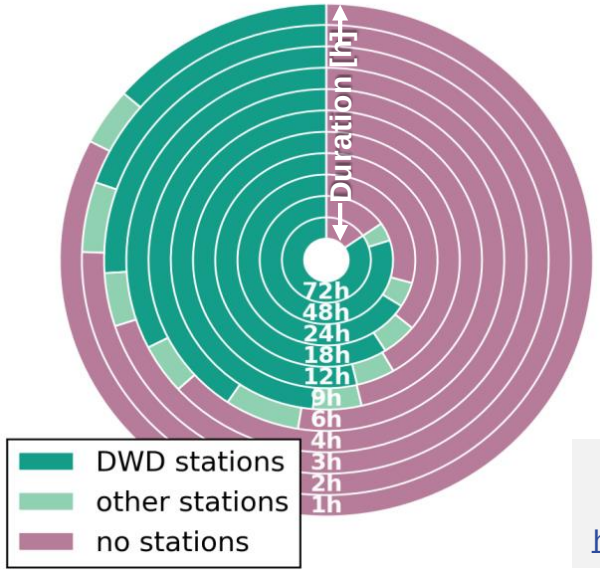
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Percentage of extreme events (2001-2018) that were measured or missed by the DWD precipitation stations

All Events (1 to 72h)



Events Duration's based



→ percentage of detected events decreases with shorter durations

→ only **33% of all events have been observed** by rain gauges (more than **75% observed for D = 24h**)

→ the **events of short duration are rarely recorded** by the point measurements (**82.7% missed for D = 1 h**)

MORE: Katharina Lengfeld et al, 2020 Environ. Res. Lett.15 08500, https://doi.org/10.1088/1748-9326/ab98b4

Radar Online Adjustment - RADOLAN

- **Hourly adjustment of the areal radar mosaic by combination with gauge-based point measurements of the hourly precipitation sum**

- Retrieval of the **ratios/differences** between radar pixel and station values
- **Spatial interpolation** of the ratios and differences
- **Application** of the ratios and differences to the unadjusted radar mosaic

- Determination of the best adjustment procedure by **online verification**
- **Weighted combination** of the two gauge-adjusted products

- **Application in flood prevention and flood protection since June 2005**

Catalogue of extreme precipitation events

Threshold applied for the detection of single precipitation objects:

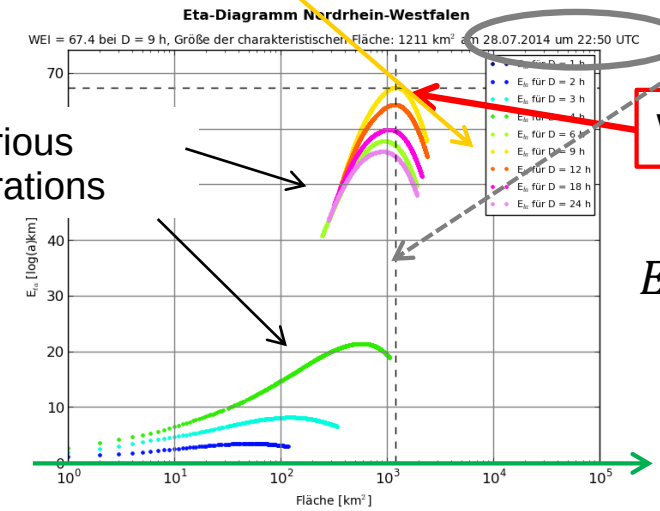
Duration [h]	1	2	3	4	6	9	12	18	24	48	72
Minimum Area [# Pixel ≈ km²]	9	9	9	12	18	27	36	54	72	144	216
Precipitation with a Return Period of 5 years (≥ 5a) [mm] based on RADKLIM	14,8 to 28,8	18,9 to 36,5	21,4 to 42,8	22,4 to 53,0	26,1 to 56,0	29,2 to 65,7	31,6 to 73,5	35,2 to 87,3	37,8 to 99,6	44,4 to 137,8	48,7 to 167,6
DWD's Warning Level 3 [mm]	≥ 25	≥ 27	≥ 29	≥ 31	≥ 35	≥ 37.5	≥ 40	≥ 45	≥ 50	≥ 60	≥ 90

Weather Extremity Index (Müller und Kašpar, 2014*)

Characteristic Durations

Characteristic area

Time step of the maximum extremity



Various durations

$$WEI = \max(E_{ta})$$

$$E_{ta} = \frac{\sum_{i=1}^{n} \log(N_{ti})}{n} \frac{\sqrt{a}}{\sqrt{\pi}}$$

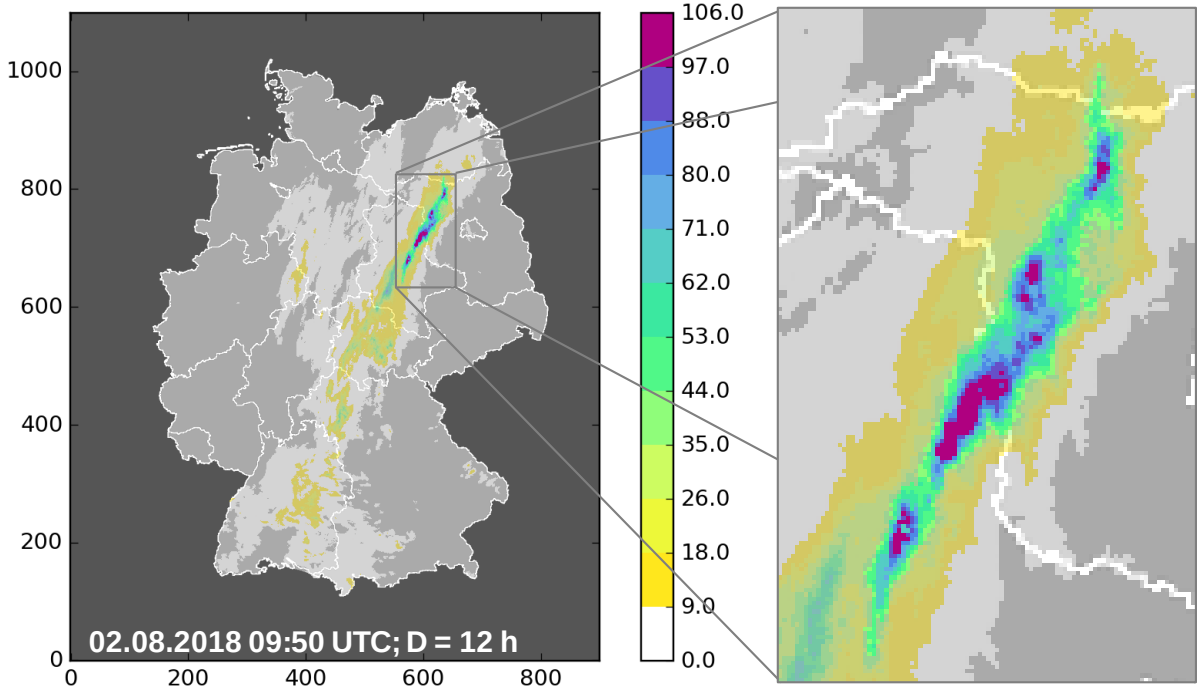
Mean log. Return Period

Area

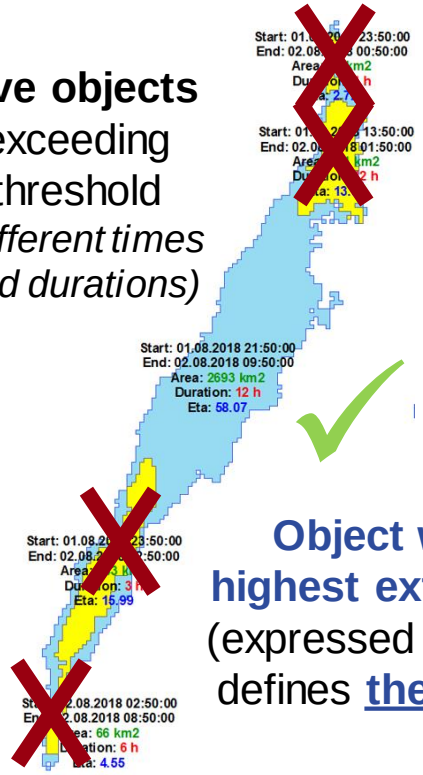
Extremity (E_{ta}) of the Event = maximal combination of mean return period, area and duration

*Müller, M. and Kaspar, M.: Event-adjusted evaluation of weather and climate extremes, Nat. Hazards Earth Syst. Sci., 14, 473-483, doi:10.5194/nhess-14-473-2014, 2014

How a spatially independent event is defined?

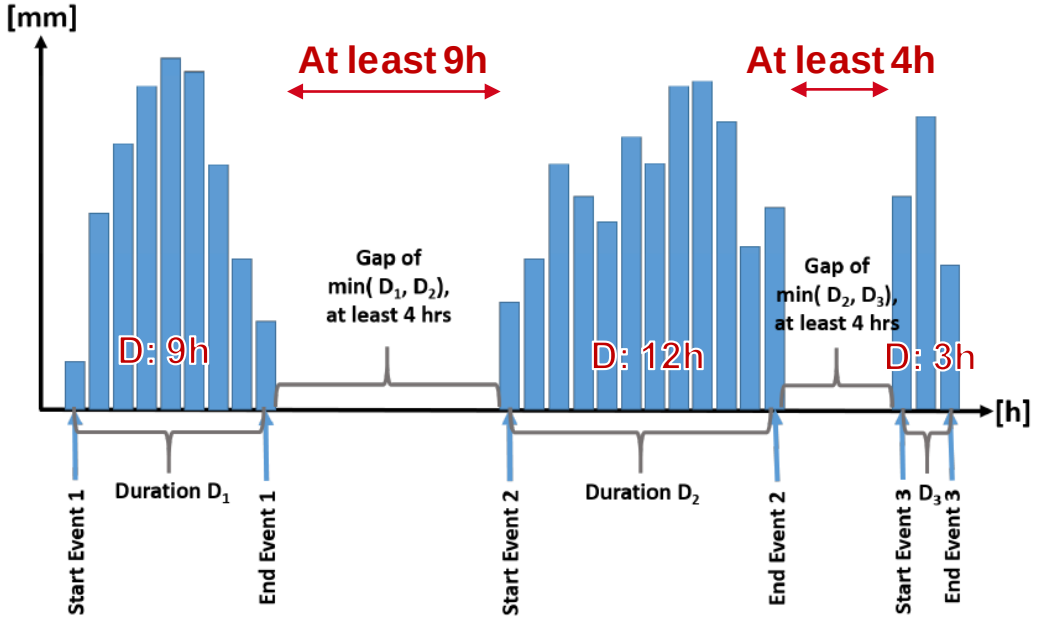


Five objects exceeding threshold *(different times and durations)*



Object with highest extremity (expressed by Eta) defines **the event**

How temporaly independent events are defined?



Scheme of the temporal independence of precipitation events.

Between two events a temporal **gap of the shorter of their durations**, but in any case **at least 4 hours** must be given.