Karlsruhe Institute of Technology

KIT-Campus Alpin
IMK-IFU: Atmosphärische Umweltforschung

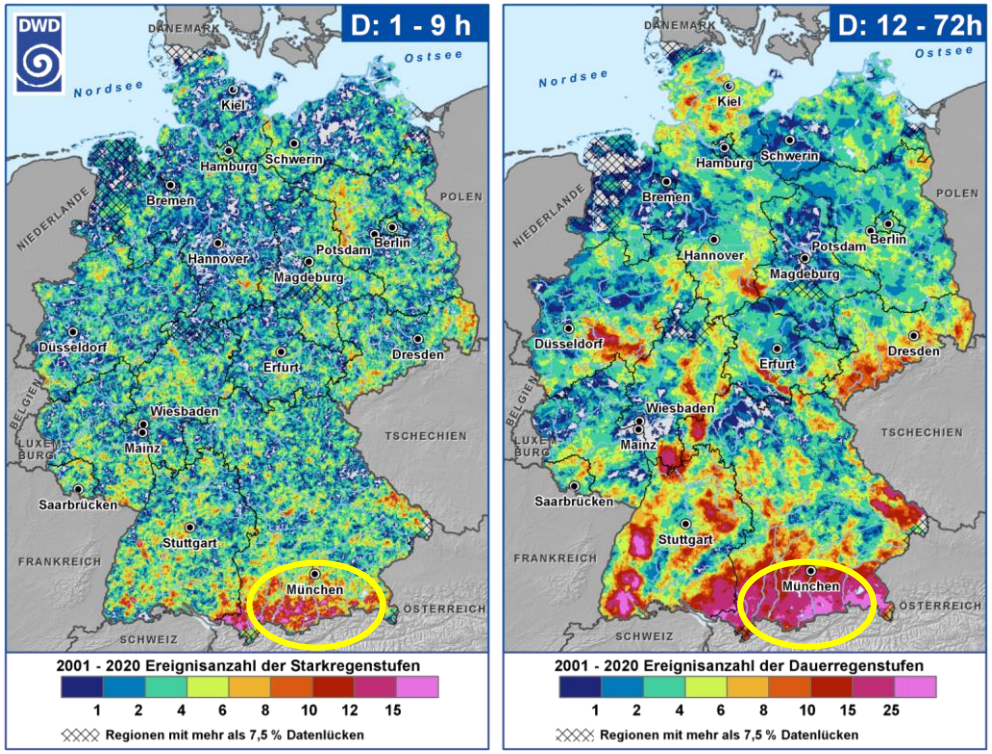
EGU General Assembly 2023
NH1.2 EGU23-6846

Dr.rer.nat. Gamze Koç | 25 April 2023

Clustering of flood-aggravating pathways in the forelands of Pre-Alpine Region

Motivation

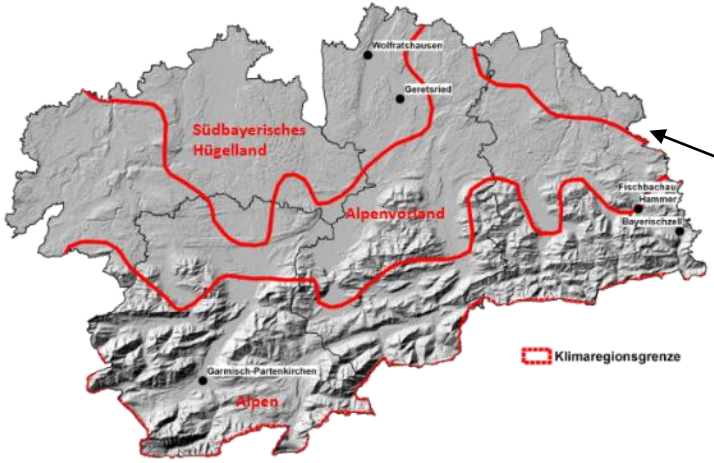
- Hotspot for severe precipitation events



Klimadaten und Darstellung: © DWD 2021 (CatRaRE Daten: 10.5676/DWD/CatRaRE_W3_Eta_v2021.01); Geodaten: © GeoBasis-DE/BKG 2020 (Stand: 01.01.2020).

Motivation

- Hotspot for risk governance
  - Dynamically growing region
  - Increased surface sealing
  - Loss of retention areas
  - Expansion of settlements into flood-prone areas



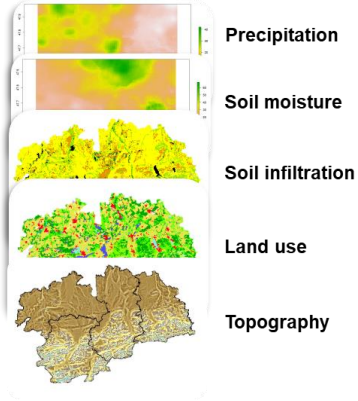
Objective

- Spatially defining the dominant flood triggering parameter for different districts of Oberland region
- To provide a general information on regional scale for a detailed hydraulic model
- Providing a base information for regional flood risk management studies

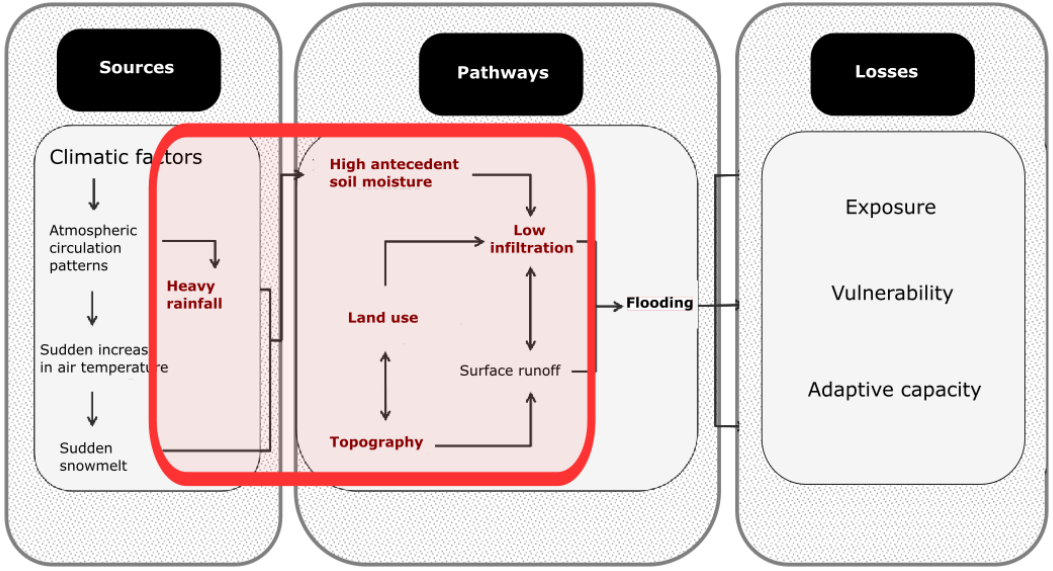
Conceptualized Model

Cluster analysis based on Source-Pathway-Consequence Model

- Evaluation of existing climate information for heavy precipitation
- Cluster analysis of precipitation, soil moisture, land use, soil infiltration and topographic parameters



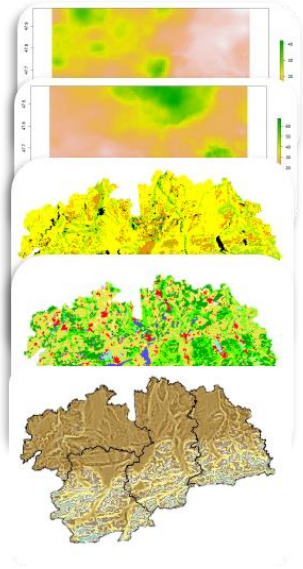
Cluster analysis



Modified from Koç et al., 2020

Spatial pattern of the dominant flood-triggering parameters

Data & Method



Precipitation

Soil moisture

Soil infiltration

Land use

Topography

cluster (version 2.1.3)

clara: Clustering Large Applications

Description

Computes a `"clara"` object, a `list` representing a clustering of the data into `k` clusters.

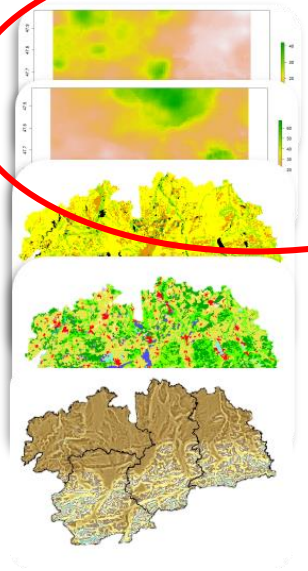
Usage

```
clara(x, k, metric = c("euclidean", "manhattan", "jaccard"),
      stand = FALSE, cluster.only = FALSE, samples = 5,
      sampsize = min(n, 40 + 2 * k), trace = 0, medoids.x = TRUE,
      keep.data = medoids.x, rngR = FALSE, pamLike = FALSE, correct.d = TRUE)
```

$$D(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2)}$$

Euclidean distance

Data & Method



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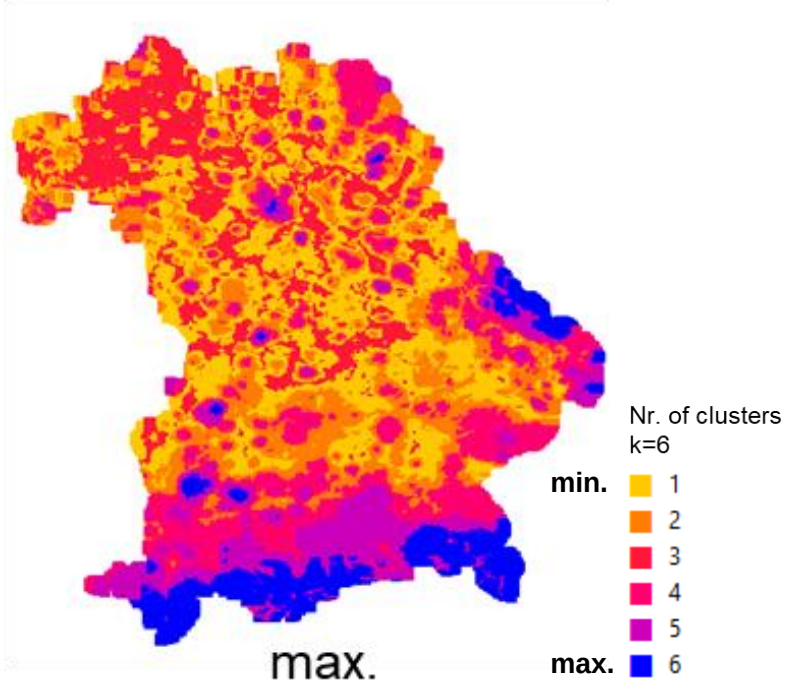
Euclidean distance

Preliminary Results*

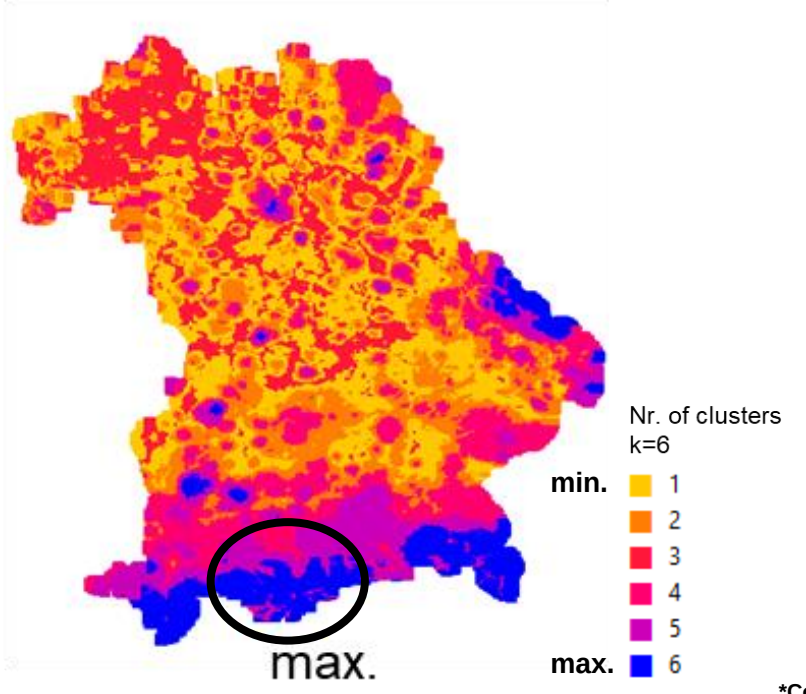
Bayern, 2001-2021, k6, Regnie Precipitation (1 km x 1 km)



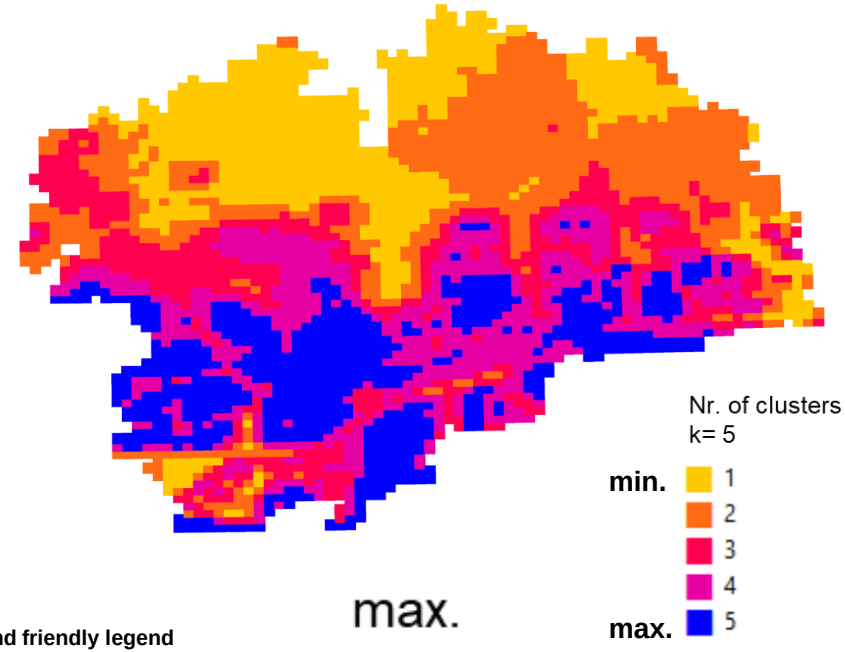
***Colour-blind friendly legend**

Preliminary Results*

Bayern, 2001-2021, k6, Regnie Precipitation (1 km x 1 km)

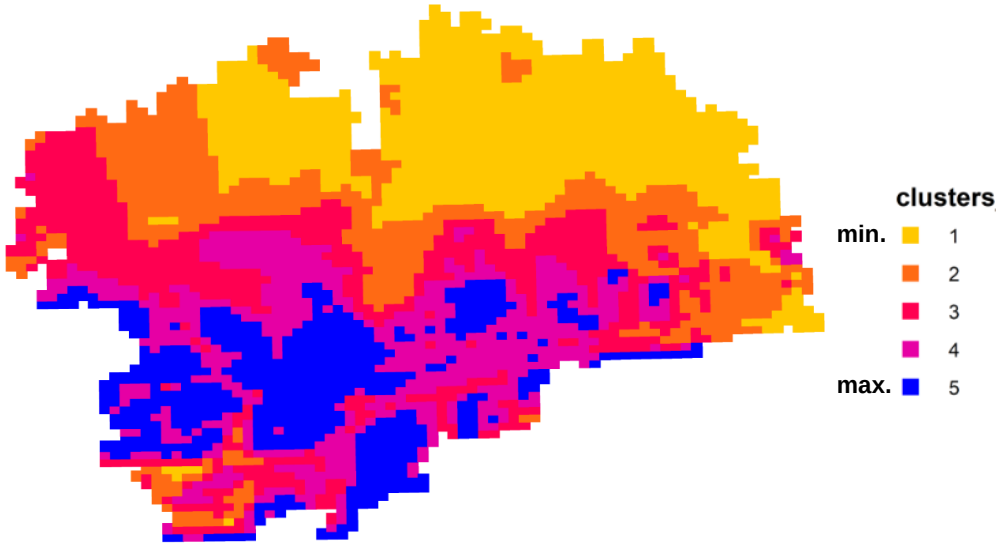


Oberland, 2001-2021, k5, Regnie Precipitation (1 km x 1 km)



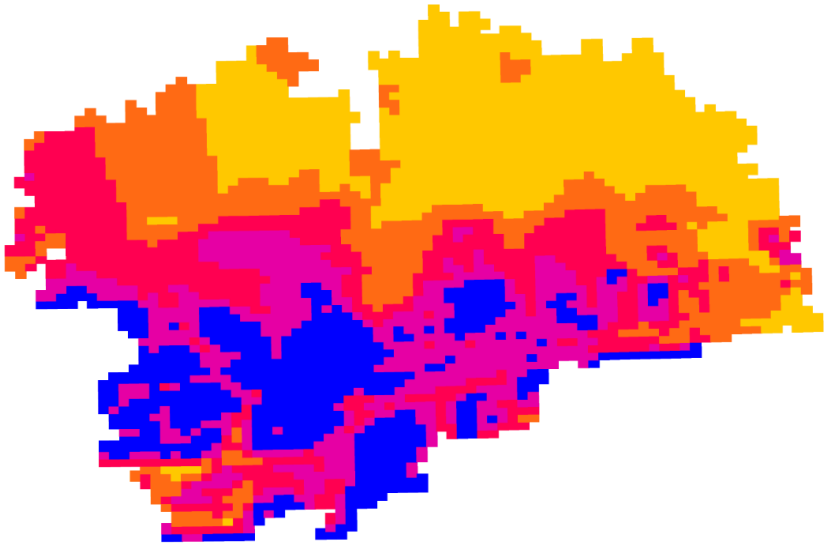
*Colour-blind friendly legend

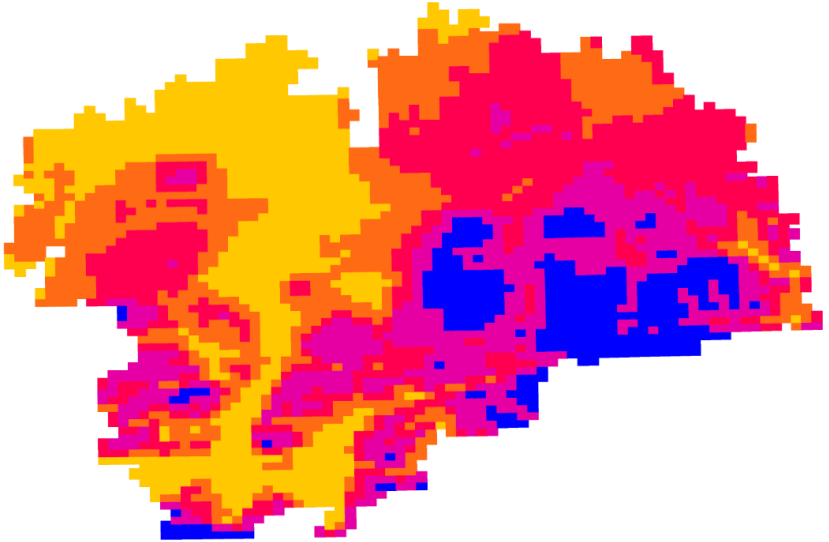
Preliminary Results – precipitation pattern



2001-2011_max_prec

Preliminary Results – precipitation pattern

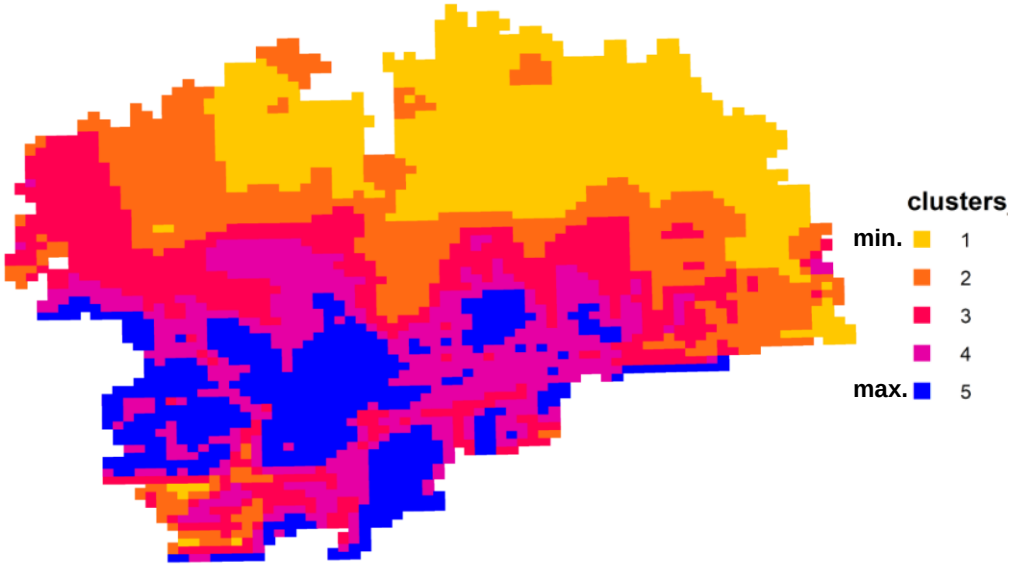




2001-2011_max_prec

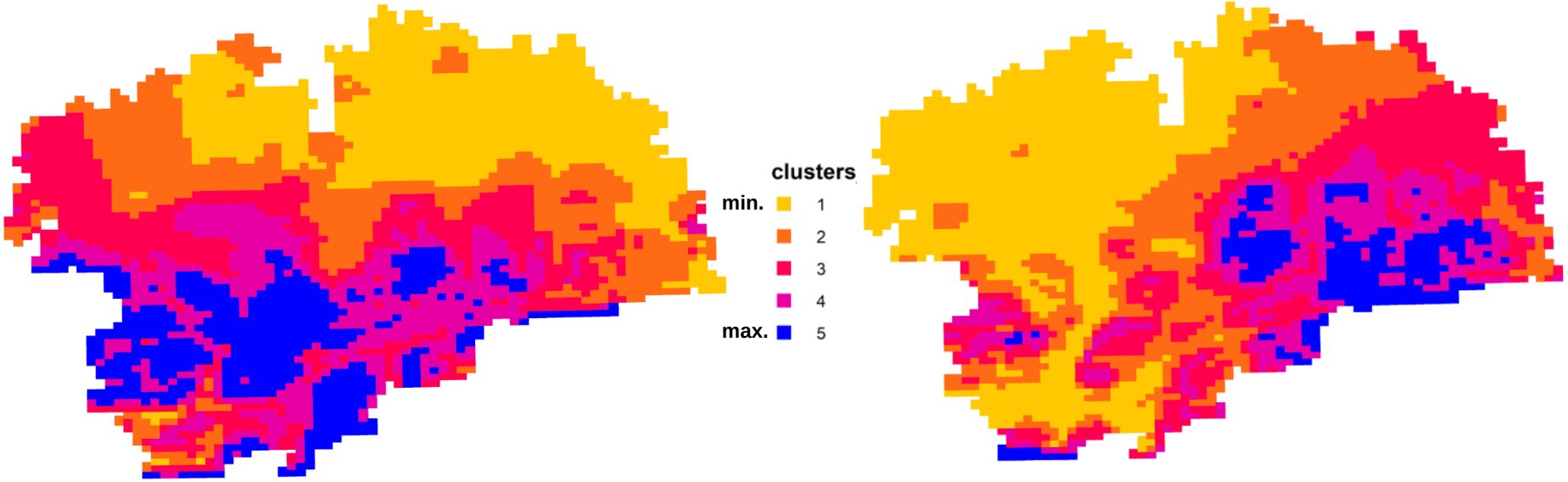
2012-2021_max_prec

Preliminary Results – precipitation pattern



2001-2011_summer_max_prec

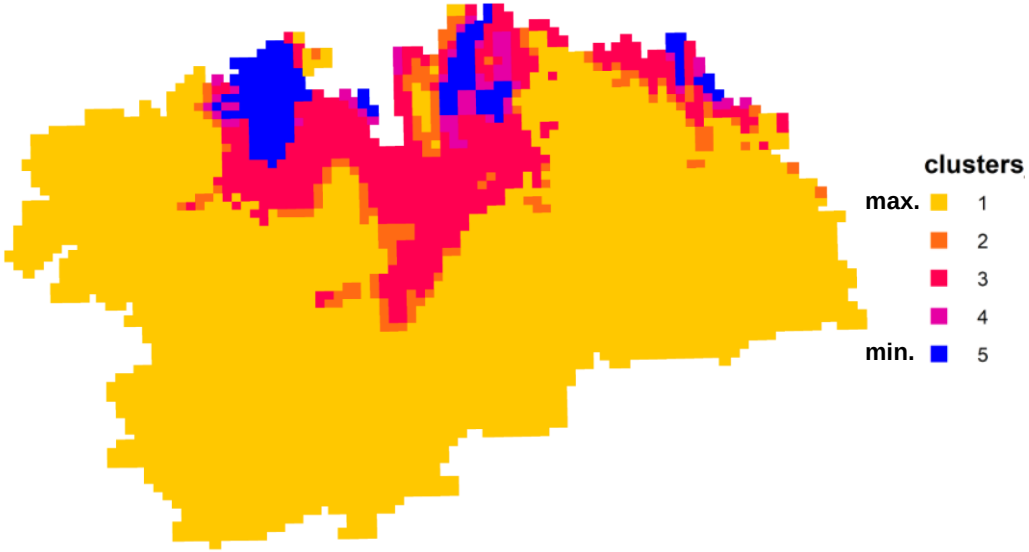
Preliminary Results – precipitation pattern



2001-2011_summer_max_prec

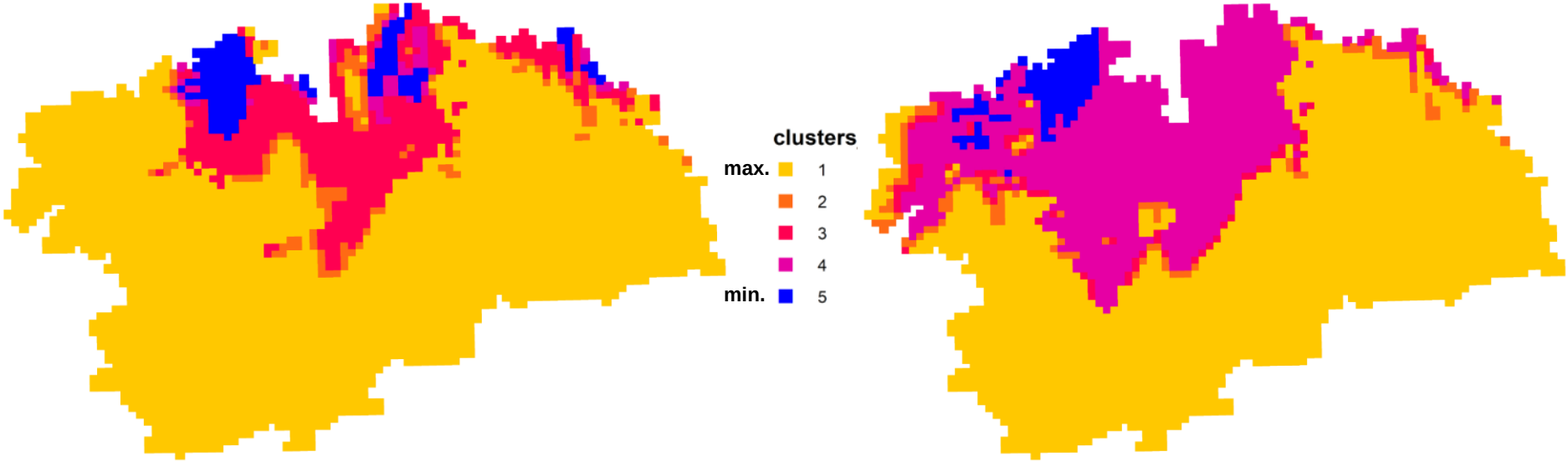
2012-2021_summer_max_prec

Preliminary Results – soil moisture pattern



2001-2011_max_sm

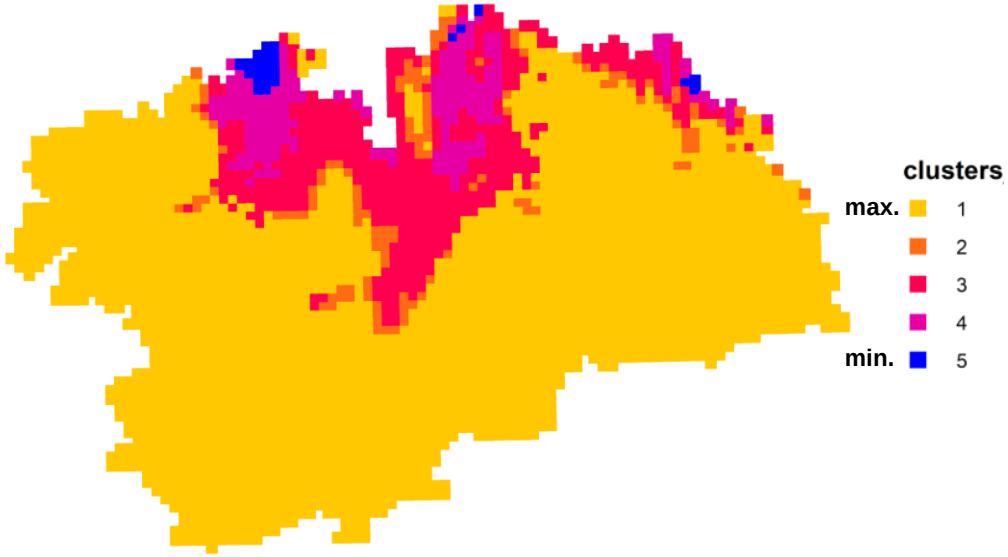
Preliminary Results – soil moisture pattern



2001-2011_max_sm

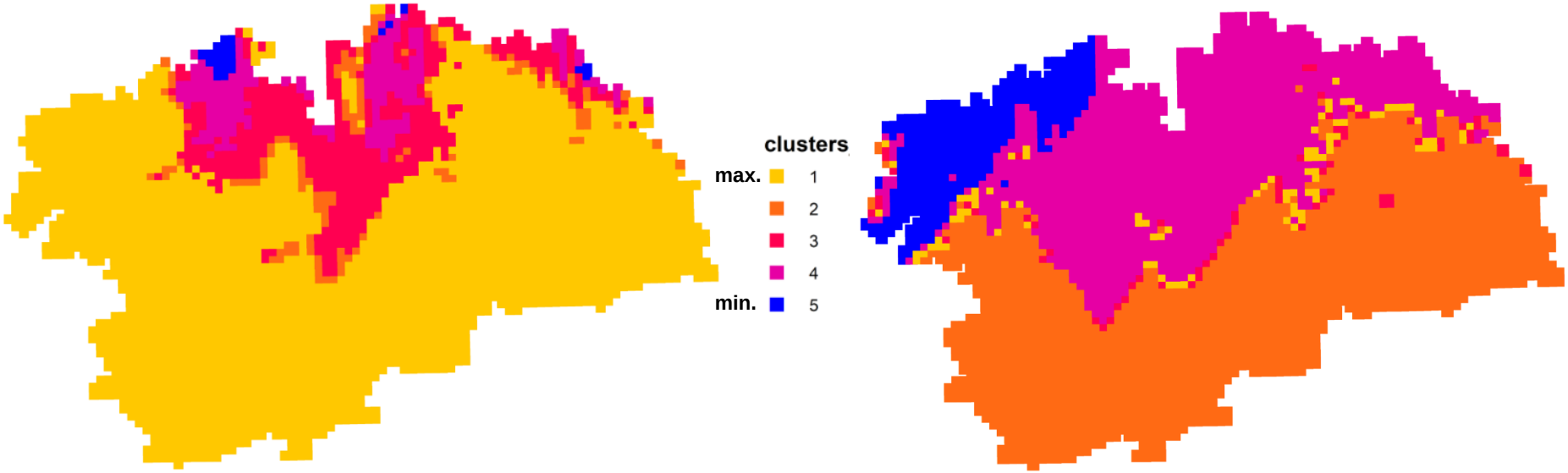
2012-2021_max_sm

Preliminary Results – soil moisture pattern



2001-2011_summer_max_sm

Preliminary Results – soil moisture pattern



2001-2011_summer_max_sm

2012-2021_summer_max_sm

Conclusion

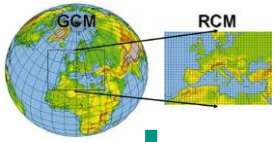
- Clustered maps mostly follow the climate boundaries of the Alpine region. However, **southern part of the Oberland (Pre-Alpine region)** does not belong to a specific cluster and **has a heterogeneous pattern.**
- **Northern part of the Pre-Alpine** region has **decreasing maximum precipitation** over the time.
- The most significant **changes of max. pecipitation and soil moisture pattern** occurs within the **last decade** (2012-2021).
- The most significant cluster pattern **changes of soil moisture** occurs within the **last decade summer** (2012-2021). **Pre-Alpine** region has **decreasing soil moisture pattern** within summer 2012-2021.
- Cluster results and their combination with other parameters (e.g. topography, land use, etc.) could help to see the **vulnerable zones for floods** with regards to high precipitation in combination with soil moisture.
- Precipitation pattern clusters could also be used as **base information for atmospheric circulation pattern clustering**, to see if there is a correlation between circulation classification pattern and precipitation pattern in the region.
- The method could be implemented with down-scaled **future climate data** to see the spatial pattern of the triggering factors.

Thank you for your attention...

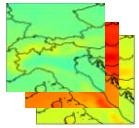
gamze.koc@kit.edu

*This work has been undertaken as a part of **KARE - Klimawandelanpassung auf regionaler Ebene** project which was funded by **BMBF - Bundesministerium für Bildung und Forschung** (01LR2006D) within the **RegIKlim - Regionale Information zum Klimahandeln** consortium.*

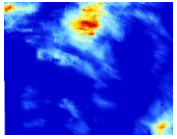
Back-up Slide - Outlook



Specialized weather classifications



Classification based downscaling



Bias - corrected RCM

Precipitation

Bottom up approach

Triggering mechanisms

Event documentation

Sources

Pathways

Receptors

Damage

Climatic Factors

Atmospheric Circulation Patterns

Heavy Rainfall

Sudden Increase in Air Temperature

Sudden Snow Melt

High Antecedent Soil Moisture

Low Infiltration

Land Use Properties (High Share of Urban Areas)

Surface Runoff

Catchment Topography

Flooding

People

Human loss, health impacts

Settlement Properties

Commerce Buildings

Property damage, economic loss

Climate change impacts

Urban development growth

• Demographic changes
• Socio-economic changes

Impact modelling

Modified from Koç et al., 2021

Back-up Slide - I

Table T1: Characteristics of each cluster for PREC parameter

	Number of clusters*	Range	Mean
Max. PREC (mm)	1	94.4 - 105.9	99.8
	2	106 - 117	111.1
	3	117.1 - 131.7	123.7
	4	131.8 - 225.6	148.4
	5	73 - 94.3	86.2
Mean PREC (mm)	1	2.5 - 3.5	3.1
	2	3.5 - 3.9	3.7
	3	3.9 - 4.6	4.2
	4	5.4- 11.1	6.1
	5	4.6 - 5.4	5.0
CV (%)	1	2.00 - 2.08	2.04
	2	2.08 - 2.25	2.12
	3	1.93 - 2.00	1.96
	4	1.70 - 1.87	1.83
	5	1.87 -.1.93	1.90
Max. PREC (JJA) (mm)	1	90.4 - 109	100.0
	2	109.1 - 128.1	118.3
	3	128.2 - 155	138.9
	4	70.4 - 90.3	81.8
	5	155.3 - 225.6	169.6
Mean PREC (JJA) (mm)	1	4.1 - 5.4	5.0
	2	5.4 - 6.0	5.7
	3	6.0 - 6.9	6.5
	4	6.9 - 7.9	7.4
	5	7.9 - 14.8	8.8
CV (JJA) (%)	1	1.77 - 1.82	1.79
	2	1.82 - 1.94	1.85
	3	1.72 - 1.77	1.75
	4	1.53 - 1.67	1.62
	5	1.67 - 1.72	1.70

Table T2: Characteristics of each cluster for SM parameter

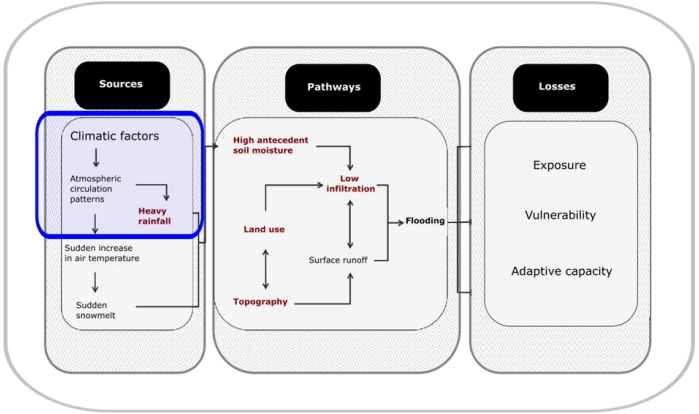
	Number of clusters*	Range	Mean
Max. SM (%NFK)	1	121.8 - 122.0	122.0
	2	121.5 - 121.8	121.6
	3	121.2 - 121.5	121.3
	4	120.5 - 121.2	121.0
	5	120.0 - 120.5	120.0
Mean SM (%NFK)	1	97.8 - 100.3	98.9
	2	100.3 - 104.0	102.1
	3	93.3 - 97.8	96.4
	4	104.1 - 107.3	105.8
	5	107.3 -110.5	108.5
CV (%)	1	11.50 - 12.52	12.06
	2	10.17 - 11.50	10.86
	3	12.52 - 14.71	13.10
	4	8.72 - 10.17	9.45
	5	7.44 - 8.71	8.24
Max. SM (JJA)(%NFK)	1	121.8 - 122.0	122.0
	2	121.4 - 121.8	121.6
	3	121.2 - 121.4	121.3
	4	120.5 - 121.2	121.0
	5	120.0 - 120.5	120.0
Mean SM (JJA (%NFK)	1	90.7 - 95.2	92.7
	2	95.2 - 101.7	98.2
	3	83.7 - 90.7	88.7
	4	101.8 - 107.3	104.8
	5	107.3 - 111.5	109.1
CV (JJA) (%)	1	14.64 - 16.18	15.65
	2	16.18 - 17.80	16.73
	3	10.41 - 12.67	11.61
	4	7.42 - 10.40	9.25
	5	12.68 - 14.63	13.65

Back-up Slide - II

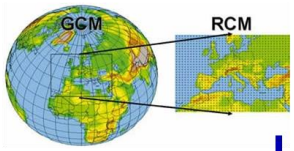
Conceptualized Source-Pathway-Damage Model for flood events in Oberland

Climate information

- Classification of weather conditions (WL) for heavy rainfall events
- Bias correction / improving density of precipitation observations
- Spatially and temporally enhanced precipitation statistics as input for hydraulic simulation and **cluster analysis**



Global & Regional Models



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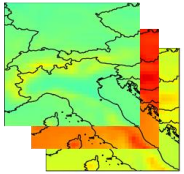
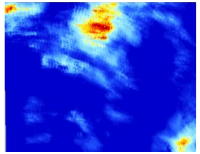


Classification based downscaling

Bias - corrected RCM

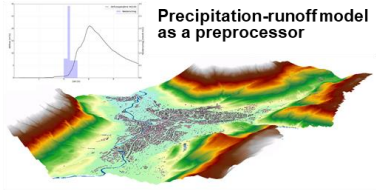


Precipitation

Back-up Slide - III

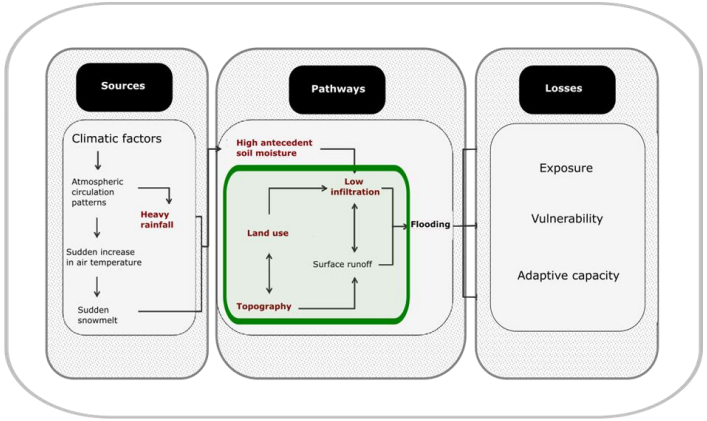
Conceptualized Source-Pathway-Damage Model for flood events in Oberland

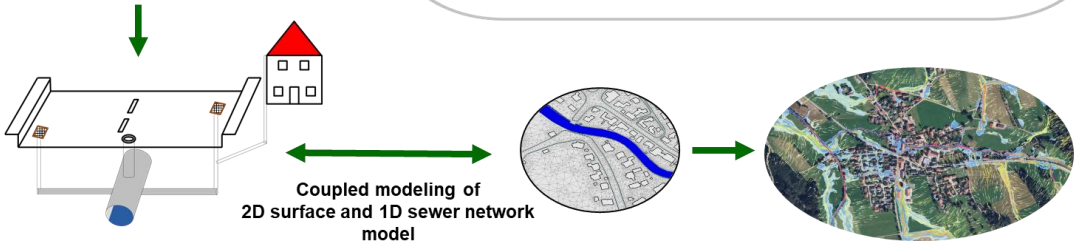
Hydraulic modelling
- Hydrological preprocessor
- 2D hydraulic surface model coupled with 1D sewer network model
- Risk analysis



Precipitation-runoff model as a preprocessor

High-resolution terrain model





Coupled modeling of 2D surface and 1D sewer network model

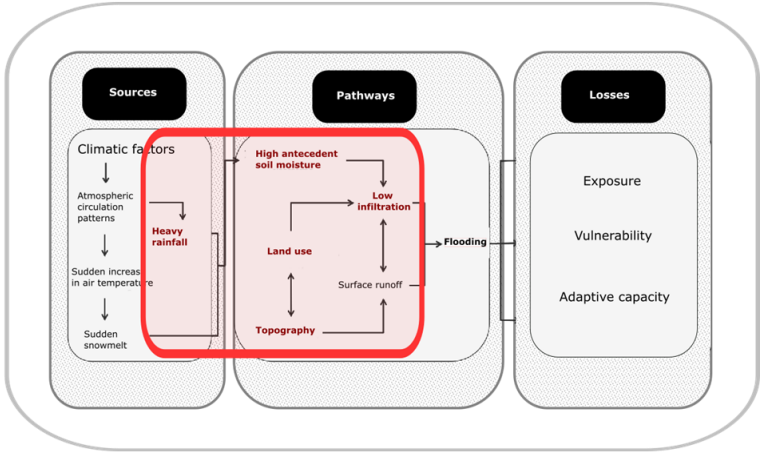
2D Hydraulic models

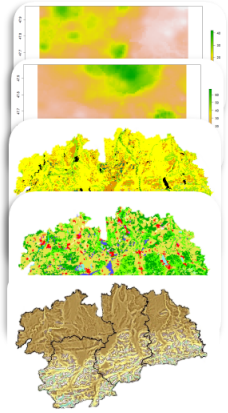
Back-up Slide - IV

Conceptualized Source-Pathway-Damage Model for flood events in Oberland

Cluster analysis based on Source-Pathway-Damage Model

- Evaluation of existing climate information for heavy precipitation
- Cluster analysis of precipitation, soil moisture, land use, soil infiltration and topographic parameters





Precipitation

Soil moisture

Soil infiltration

Land use

Topography

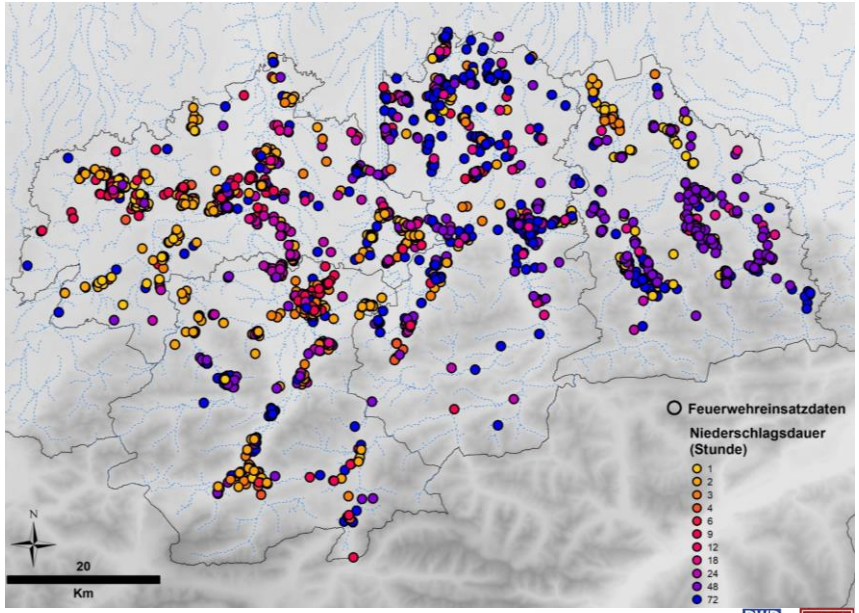
Cluster analysis

Regional flood risk maps

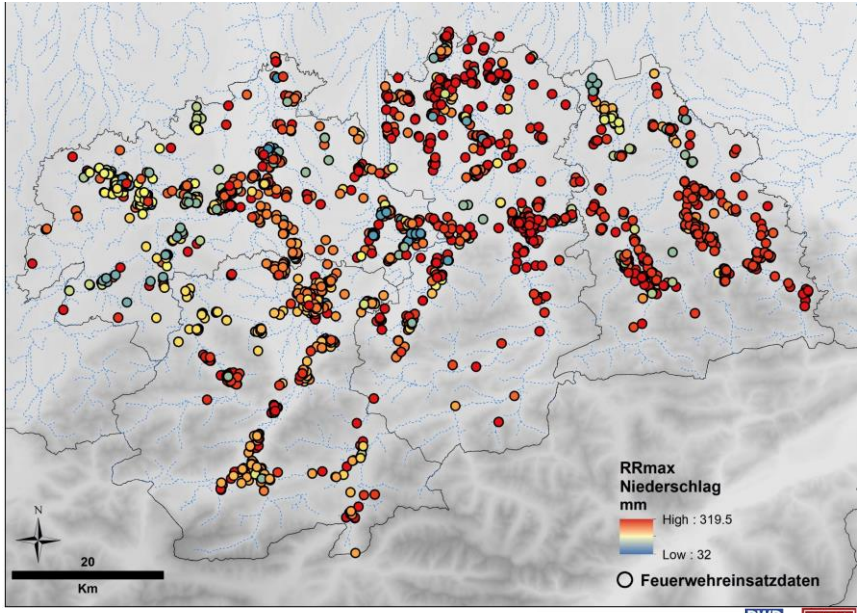
spatial pattern of the dominant flood-triggering parameters

Back-up Slide - V

Comparison of Cluster Results with Firebrigade Operations



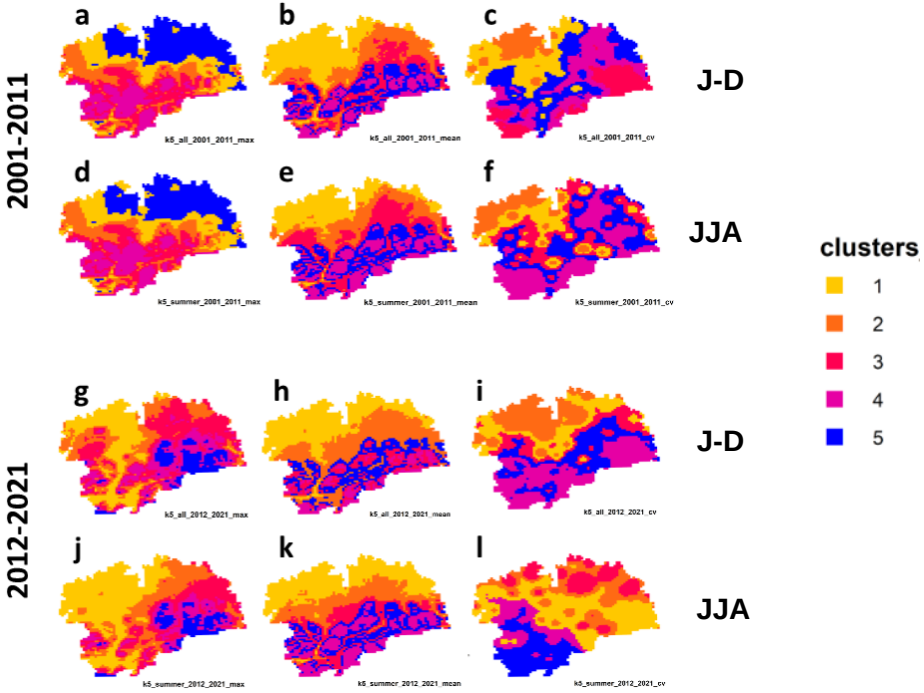
Koc, 2022



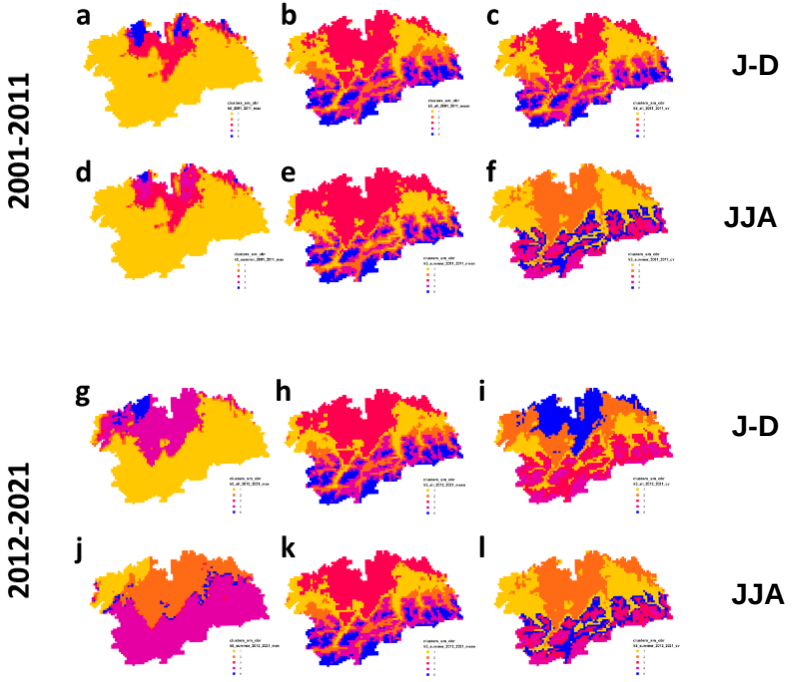
Koc, 2022

Back-up Slide - VI

Precipitation pattern



Soil moisture pattern

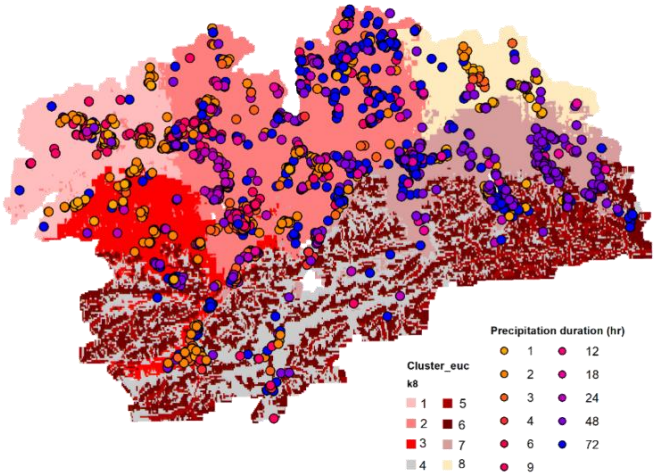


Back-up Slide - VII

Event-based clustering with *Euclidean Distance*

Sample size: **153 event days**, outcome of CatRaRE & Firebrigade data analysis

k = 8



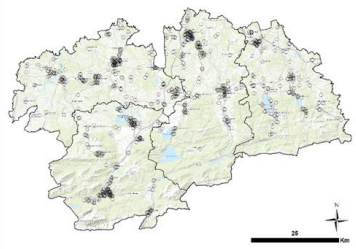
Cluster	Soil_mois	Soil_inf	DEV	Dominant triggering factor
k1	▬	↓↓	3.2×10^{-3}	Low soil infiltration
k2	▬	↑↑↑	-8.5×10^{-3}	Precipitation
k3	↑	↓↓	-0.012	Low soil infiltration
k4	↑	↑↑	-0.12	Topography
k5	↑↑	↑	-0.38	Very high soil moisture
k6	↑↑	↑	0.31	Very high soil moisture
k7	↑	↓	-0.02	High soil moisture & low infiltration
k8	▬	↓↓↓	9×10^{-4}	Very low soil infiltration

Koc, 2022

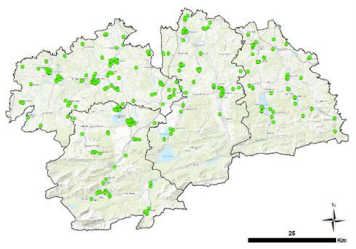
Back-up Slide - VIII

Affected and non-affected households in the survey

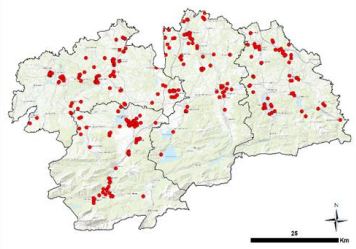
No experience, no damage



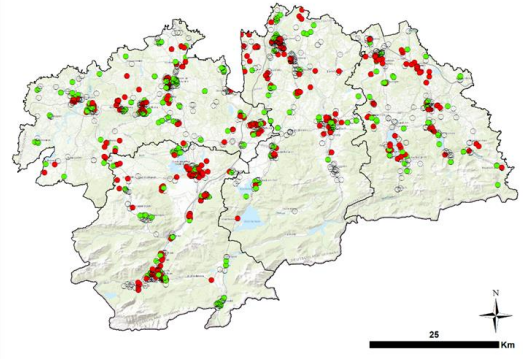
Experience, but no damage

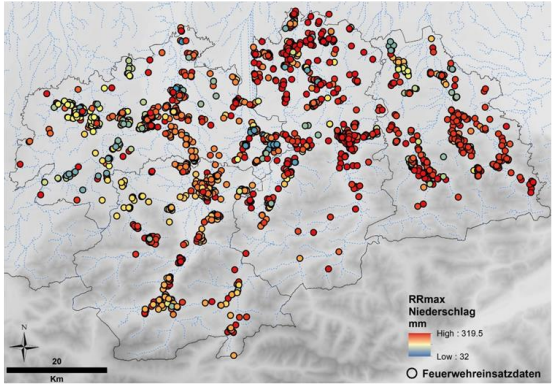


Experience and damage



All households





Schubert, et al., 2022