EGU General Assembly 2023
Session GM4.2
EGU23-12827

Hydro-sediment event types and associated conditions and processes in an alpine catchment

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MOTIVATION AND AIM

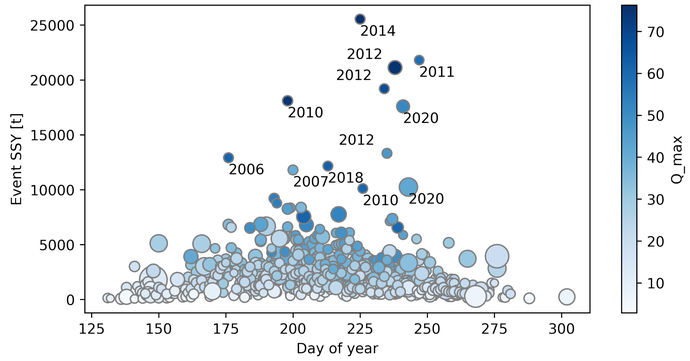
Recent changes to mountain cryosphere and climate affects sediment fluxes in high mountain areas [1]

➡ **Can we find types of hydro-sediment events that correspond to certain combinations of driving process and catchment conditions?**

METHODS

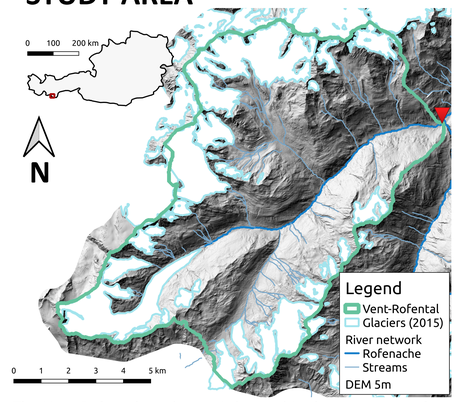
- **Event detection** from streamflow (Q) time series (2006-2020) using local minimum method [2,3], filtering out events with missing suspended sediment records or low peak suspended sediment concentration (SSC)
- **Clustering** based on Q and SSC characteristics of events
  - Calculate **hydro-sediment event metrics** from SSC and Q time series, e.g. suspended sediment yield (SSY), peak Q, hysteresis index [2], etc.
  - Pre-process **event metrics** with standard scaling and dimensionality reduction with **principal component analysis** (PCA): 16 metrics → 7 principal components
  - **Clustering** using gaussian mixture model (GMM) with spherical covariance type
- Evaluate **event types** by assessing associated catchment conditions and driving processes
  - Calculate **catchment metrics** of water and energy conditions, e.g. antecedent precipitation and temperature, and driving process, e.g. precipitation intensity

HYDRO-SEDIMENT EVENTS



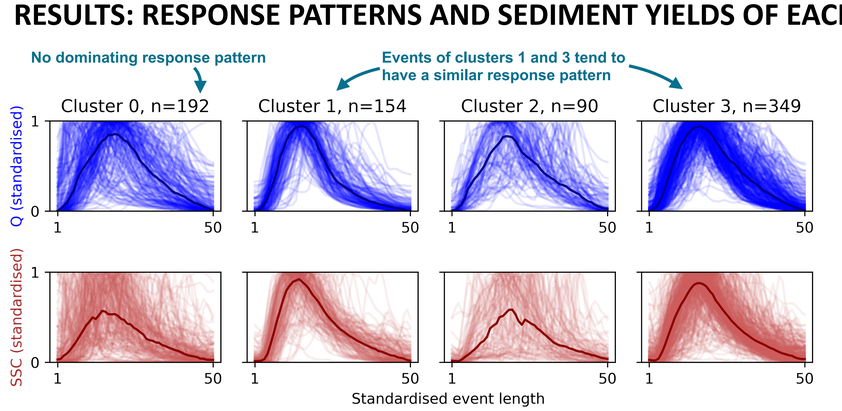
Distribution of *detected hydro-sediment events* (n=797) throughout the year. Dot size corresponds to event duration. The largest events in terms of total sediment exported (SSY) are associated with high peak streamflow.

STUDY AREA

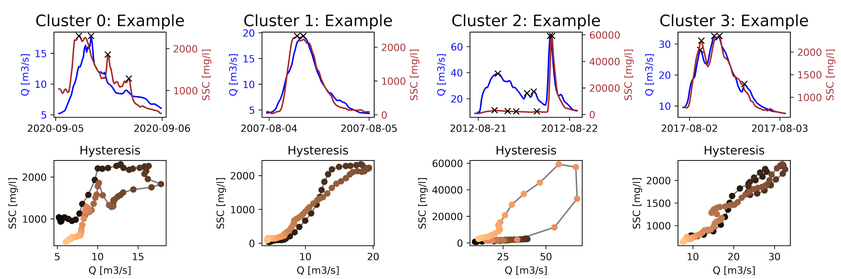


The *Vent-Rofental catchment* is located in the upper part of Ötztal valley in Tirol, Austria. The catchment area is 98 km² and spans an elevation range of 1891 to 3772 m.a.s.l. and contains several large glaciers.

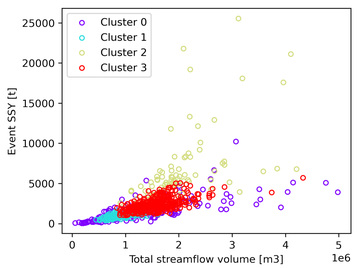
RESULTS: RESPONSE PATTERNS AND SEDIMENT YIELDS OF EACH CLUSTER



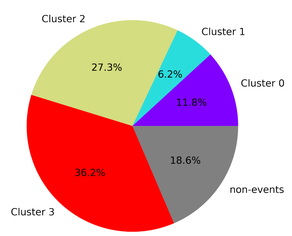
Event response and hysteresis patterns do not appear to be an important factor distinguishing the clusters. Only two of the clusters (1 and 3) appear to have a consistent Q and SSC response patterns within the cluster. Additionally, cluster 1 events tend have a rapid onset.



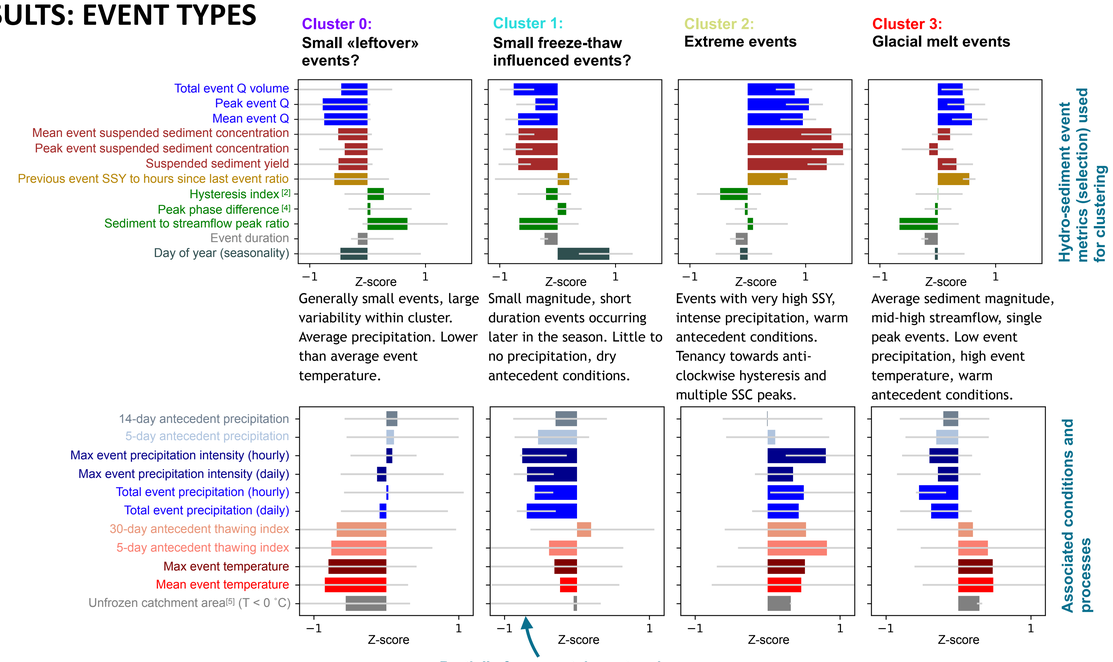
Clusters 0 and 2 both have high streamflow volume, but cluster 0 has much higher SSY



Events of cluster 2 and 3 are on average responsible for 27.3 % and 36.2 % of annual SSY respectively. While cluster 2 events have a much higher individual SSY, cluster 3 events, being more numerous, overall contribute more sediment.



RESULTS: EVENT TYPES



Generally small events, large variability within cluster. Average precipitation. Lower than average event temperature.

Small magnitude, short duration events occurring later in the season. Little to no precipitation, dry antecedent conditions.

Events with very high SSY, intense precipitation, warm antecedent conditions. Tenancy towards anti-clockwise hysteresis and multiple SSC peaks.

Average sediment magnitude, mid-high streamflow, single peak events. Low event precipitation, high event temperature, warm antecedent conditions.

Partially frozen catchment and low event temperatures indicate freeze-thaw processes?

CONCLUSIONS AND OUTLOOK

- Clustering events based only on streamflow- and suspended-sediment-derived metrics yields event types that correspond to certain combinations of catchment conditions and driving processes.
- The largest events are associated with high precipitation intensities and amounts combined with warm antecedent conditions.
- Events associated with glacial melt are the most numerous and are on average responsible for 36 % of annual suspended sediment yield.
- Outlook: Include further variables to assess the associated conditions and processes of event types, e.g. snow cover, global radiation.

Sharing is encouraged

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1. Zhang, et al. (2022). Warming-driven erosion and sediment transport in cold regions. Nature Reviews Earth & Environment.
2. Tsyplenkov, et al. (2020). Suspended sediment budget and intra-event sediment dynamics of a small glaciated mountainous catchment in the Northern Caucasus. Journal of Soils and Sediments, 20(8), 3266-3281.
3. Sloto, et al. (1996). HYSEP: A Computer Program for Streamflow Hydrograph Separation and Analysis. In Water-Resources Investigations Report.
4. Haddadchi & Hicks (2021). Interpreting event-based suspended sediment concentration and flow hysteresis patterns. Journal of Soils and Sediments, 21(1), 592-612.
5. Li, et al. (2021). Air Temperature Regulates Erodible Landscape, Water, and Sediment Fluxes in the Permafrost-Dominated Catchment on the Tibetan Plateau. Water Resources Research, 57(2), 1-14.

Supplementary material: EGU23-12827

Hydro-sediment event types and associated conditions and processes in an alpine catchment

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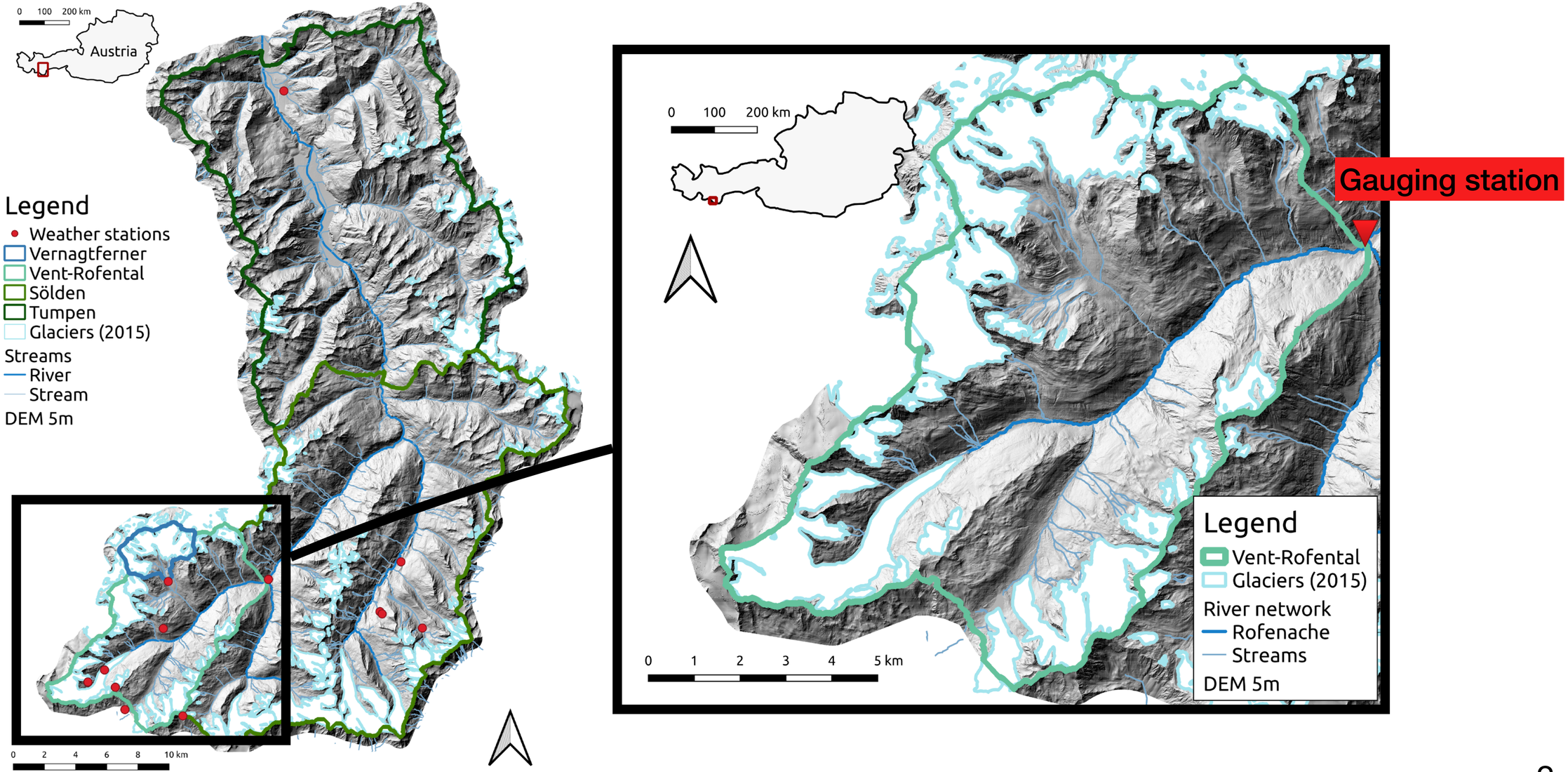
Photo: Confluence of Rofenache and Vernagtbach, 11.08.2021 © Dr. Franziska Koch

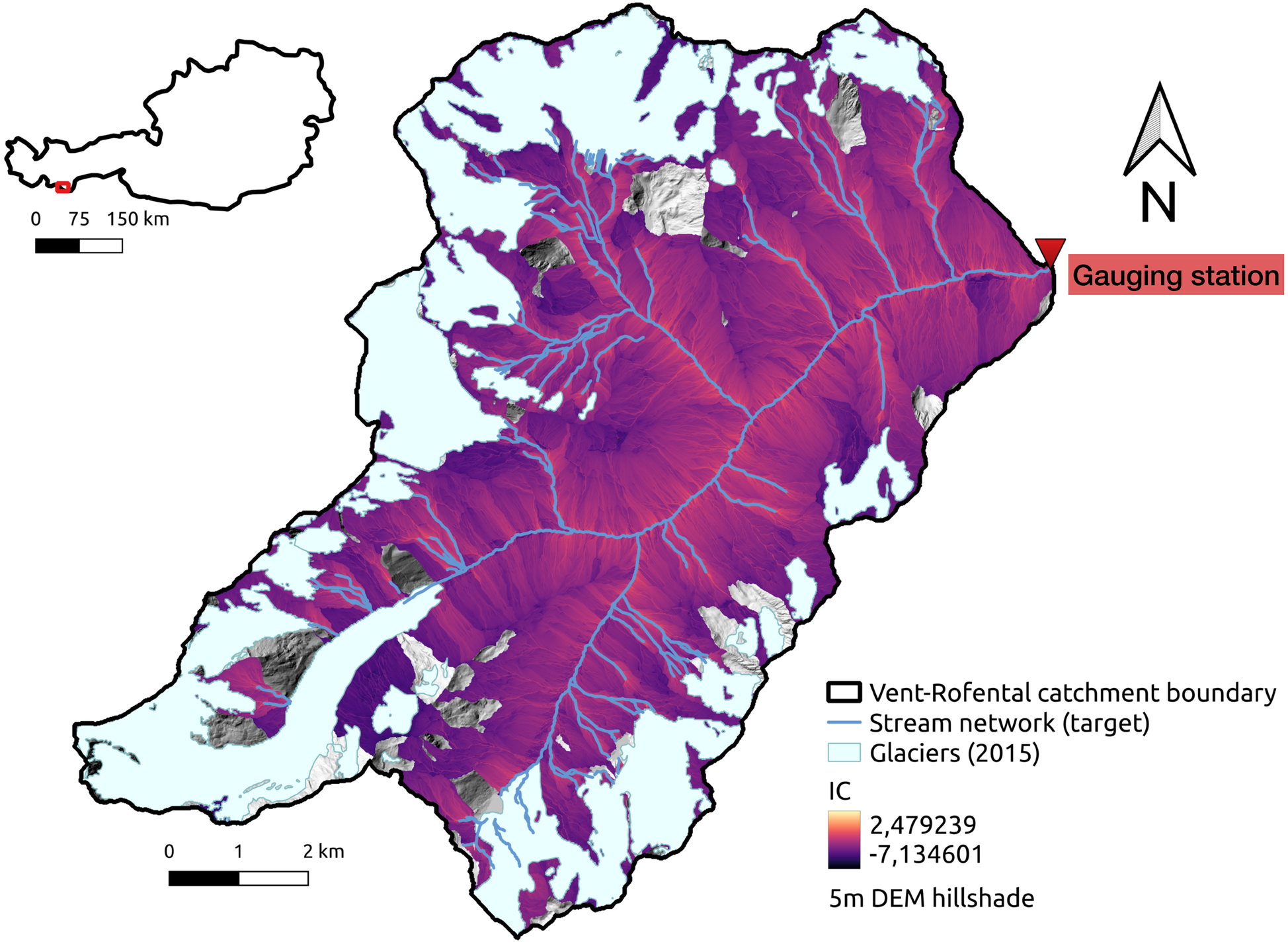
Study area

Vent-Rofental, Upper Ötztal, Austria



Connectivity

Study area



Study area

Photo: Confluence of Rofenache and Vernagtbach, 11.08.2021 © Dr. Franziska Koch

Study area

Photo: Vernagtferner, 24.09.2021 © Bayerische Akademie der Wissenschaften

Study area

Photo: Vernagtbach, July 2022 © A. Skålevåg

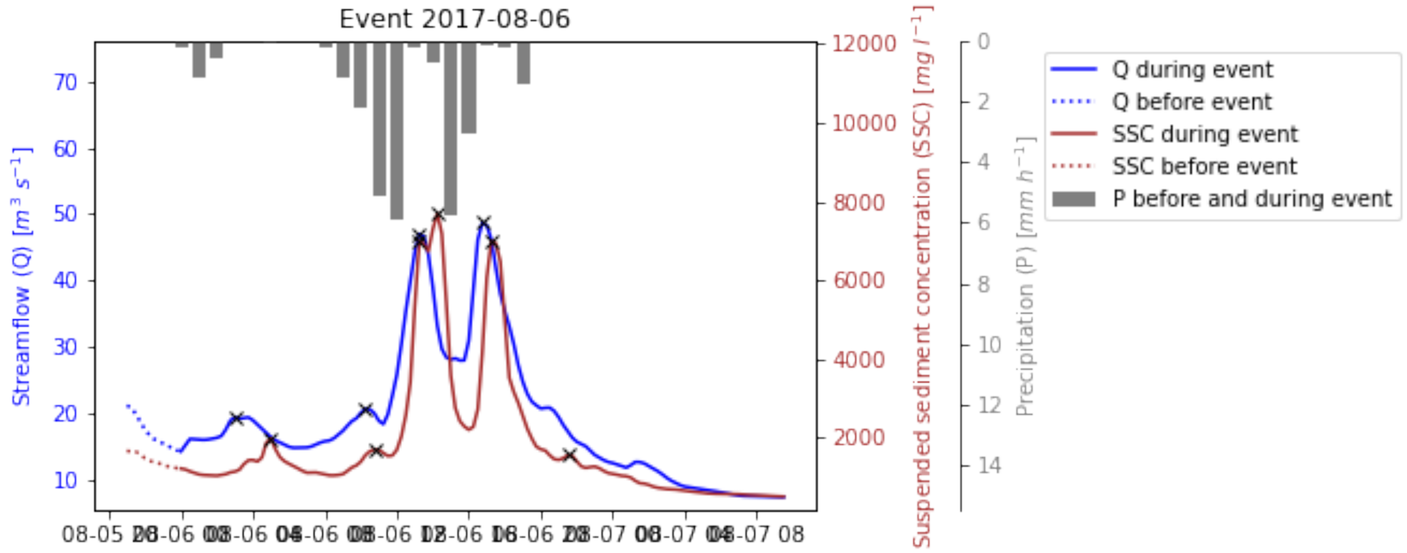
Study area

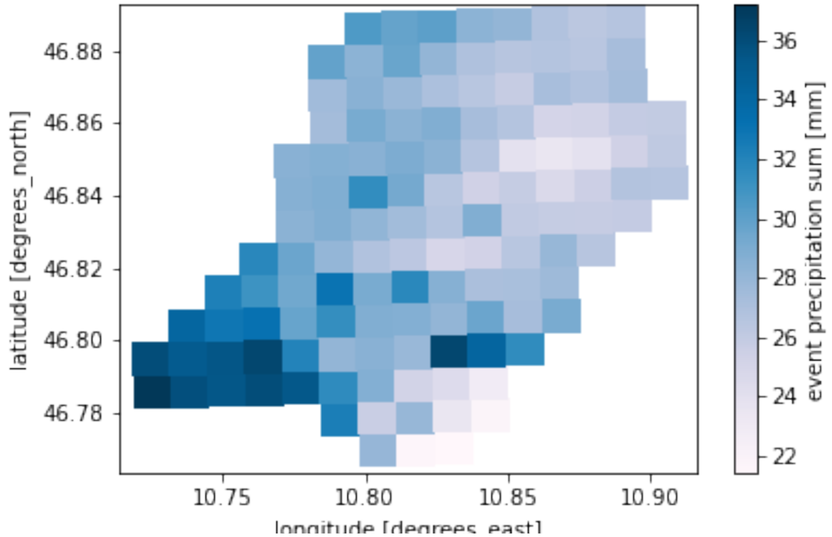
Photo: Hintereisferner, 13.06.2021 © Universität Innsbruck

Data and methods

Event catalogue

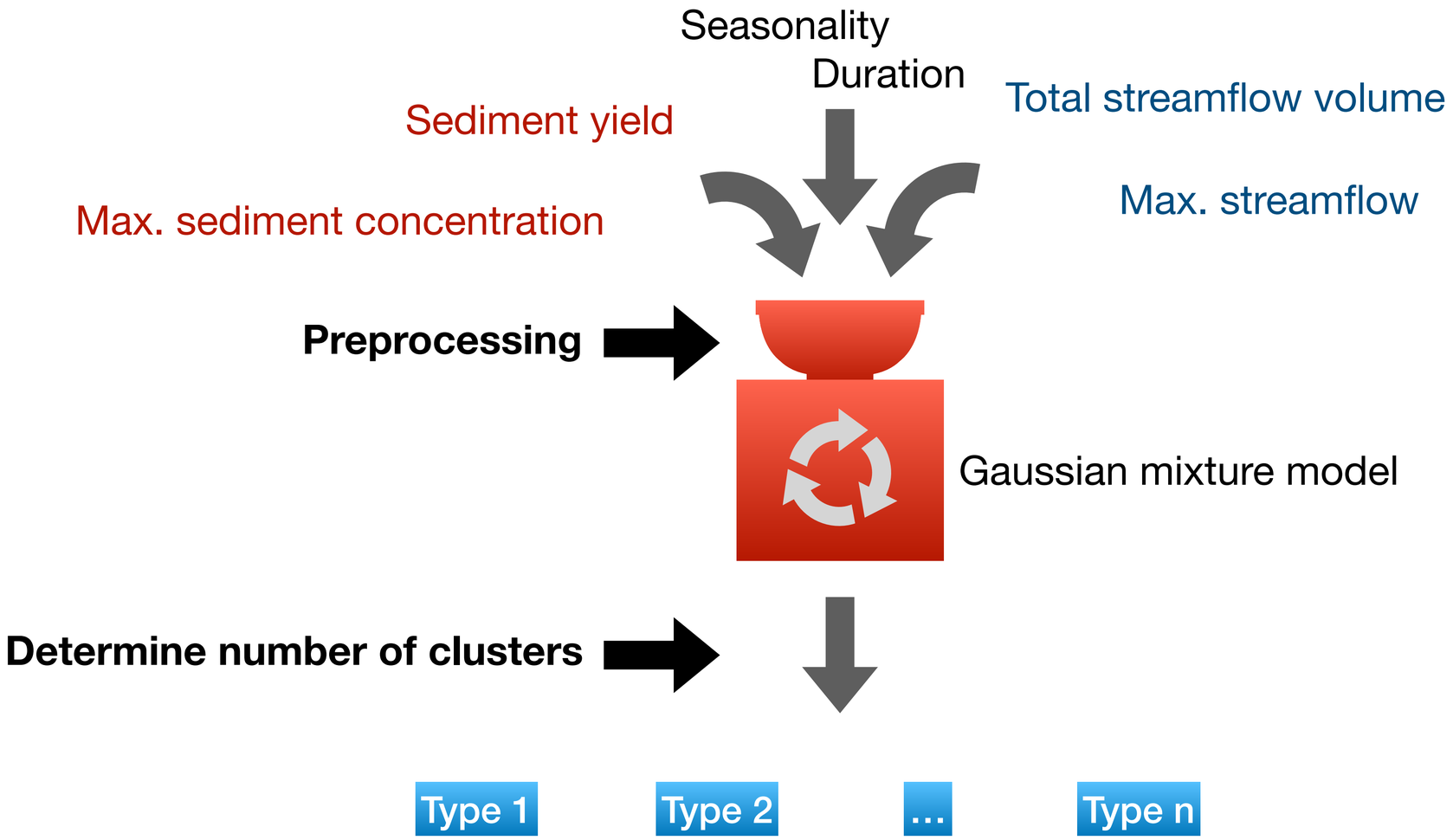
- 797 hydro-sediment events
- Between 2006-2020 (Apr-Oct)





Data and methods

Clustering approach



Event metrics

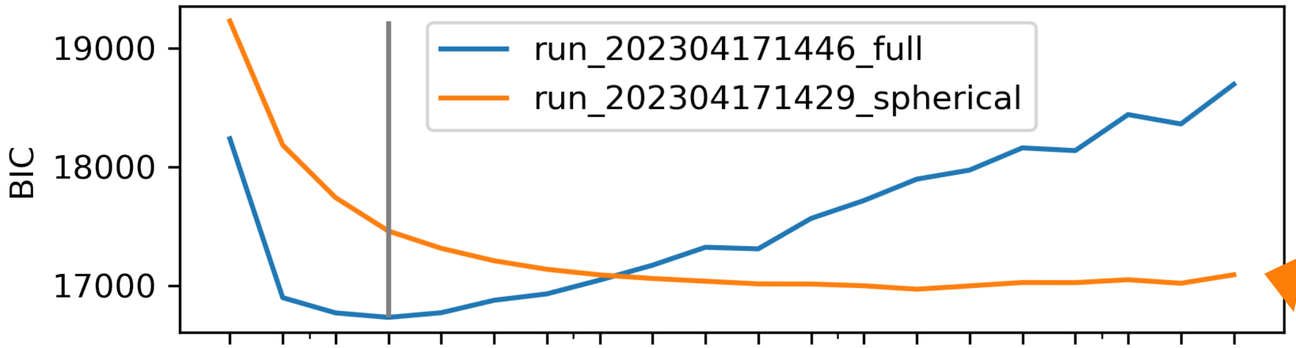
Clustering

Event types

Selecting number of clusters

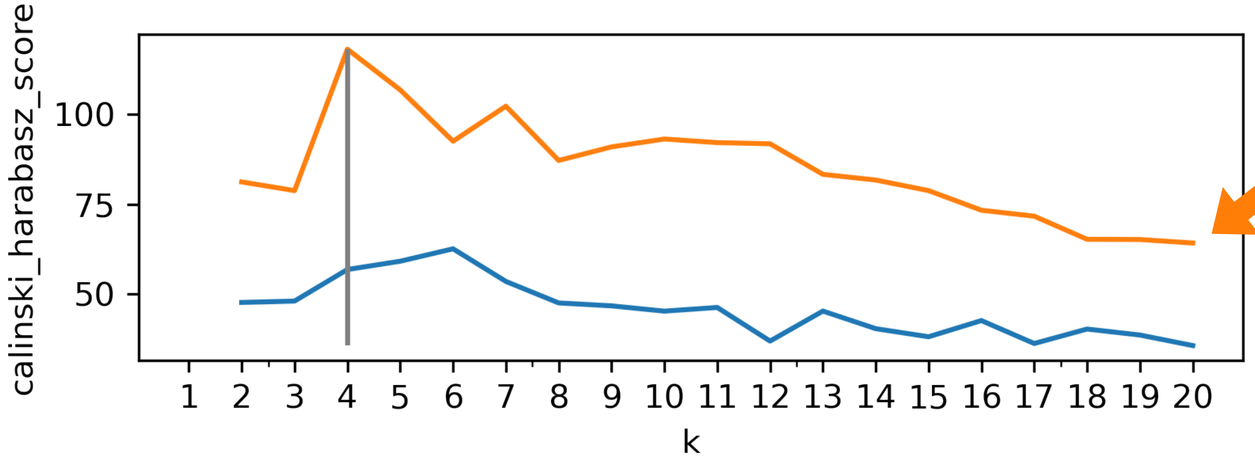
4 clusters selected as the optimal number

BIC penalizes additional parameters

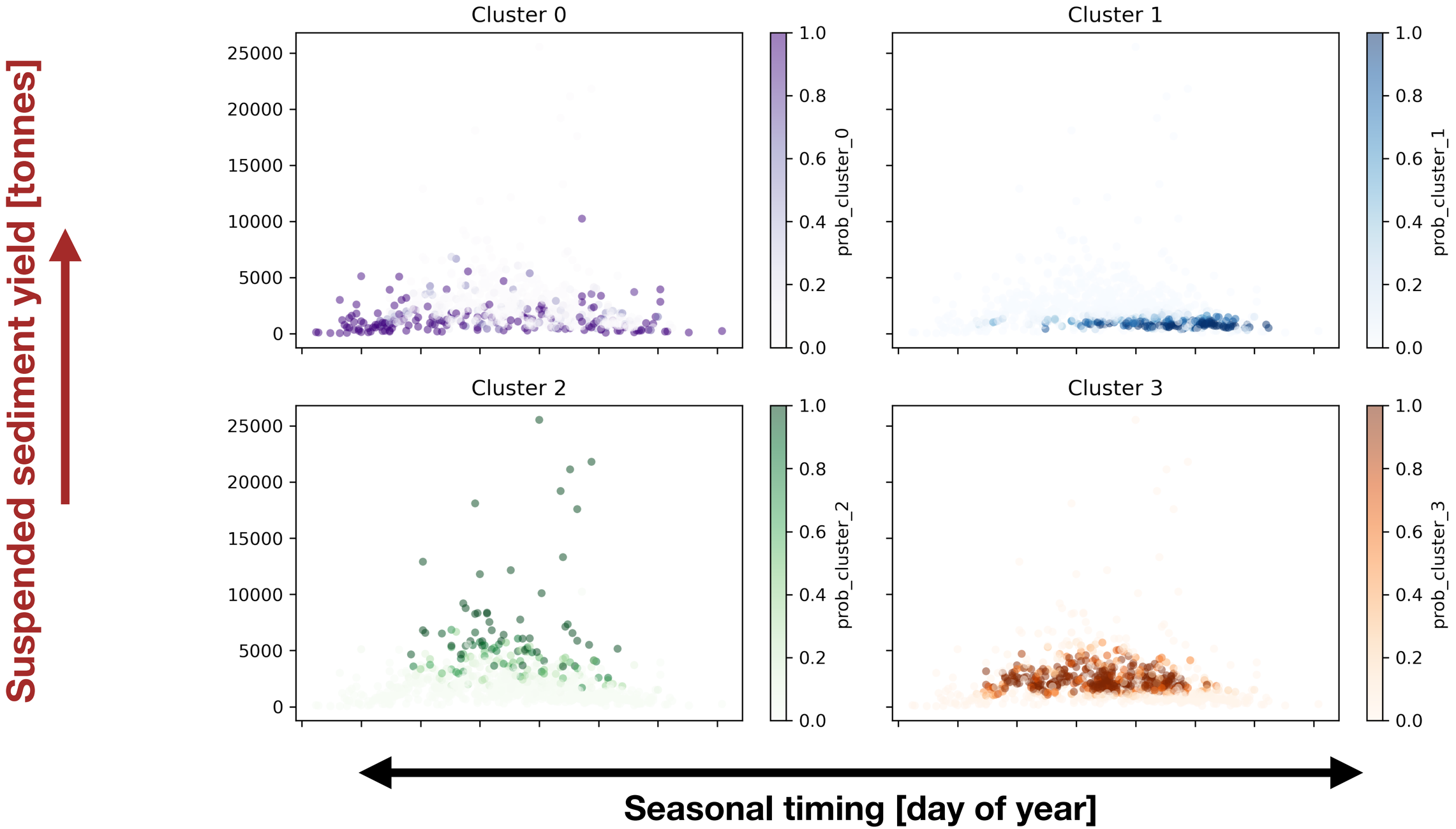


Spherical covariance type:
1 parameter for cluster shape

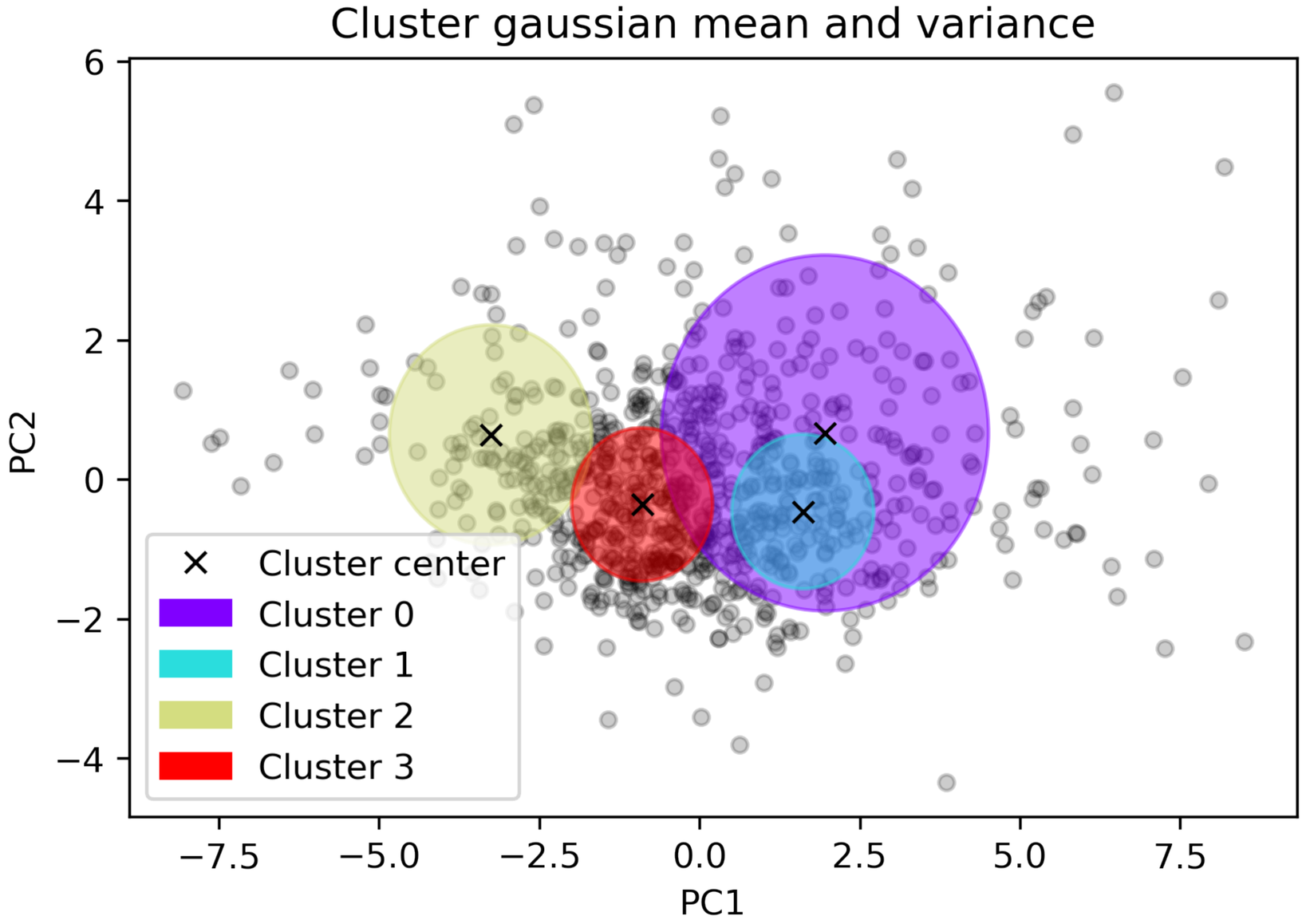
High score indicates better defined clusters



Results


Cluster 0
Cluster 1
Cluster 2
Cluster 3
25000
20000
15000
10000
5000
0
1.0
0.8
0.6
0.4
0.2
0.0
prob_cluster_0
prob_cluster_1
prob_cluster_2
prob_cluster_3
Suspended sediment yield [tonnes]
Seasonal timing [day of year]

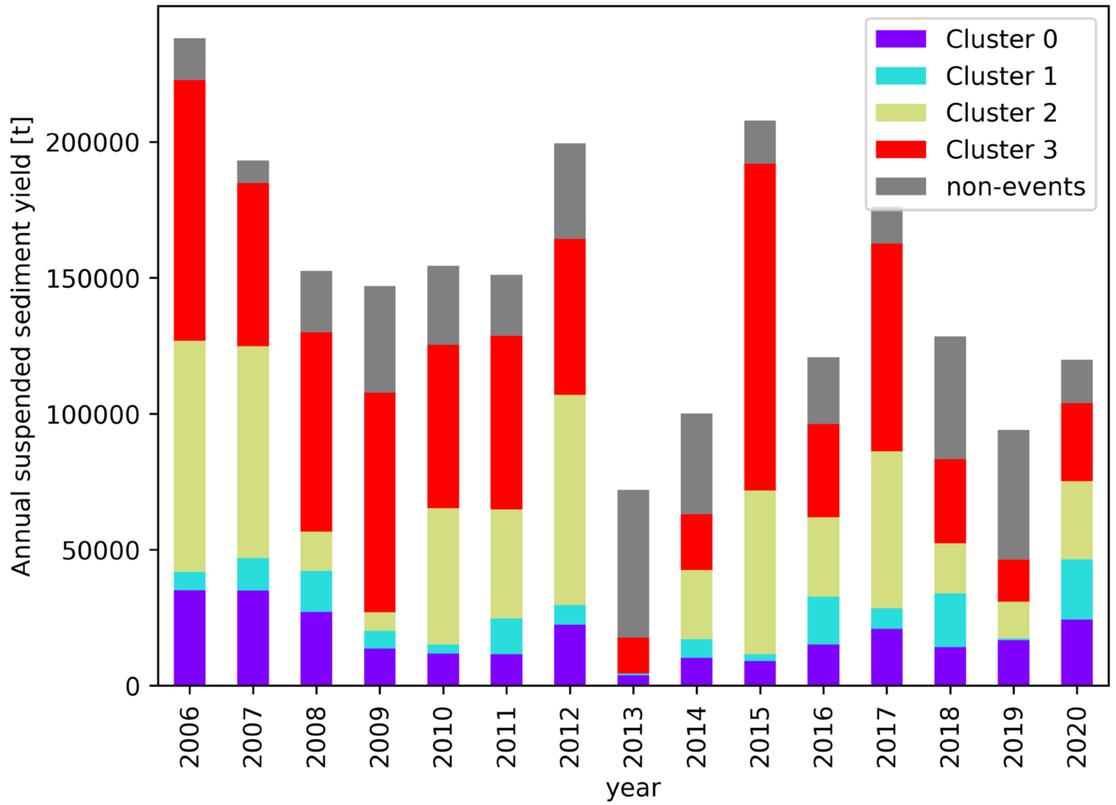
Results


Cluster gaussian mean and variance
PC2
PC1
6
4
2
0
−2
−4
−7.5
−5.0
−2.5
0.0
2.5
5.0
7.5
Cluster center
Cluster 0
Cluster 1
Cluster 2
Cluster 3

Results

Annual SSY of each cluster

Inter-annual variability



Average proportion of annual SSY