Hydrological drought monitoring at EU level through a novel low-flow index

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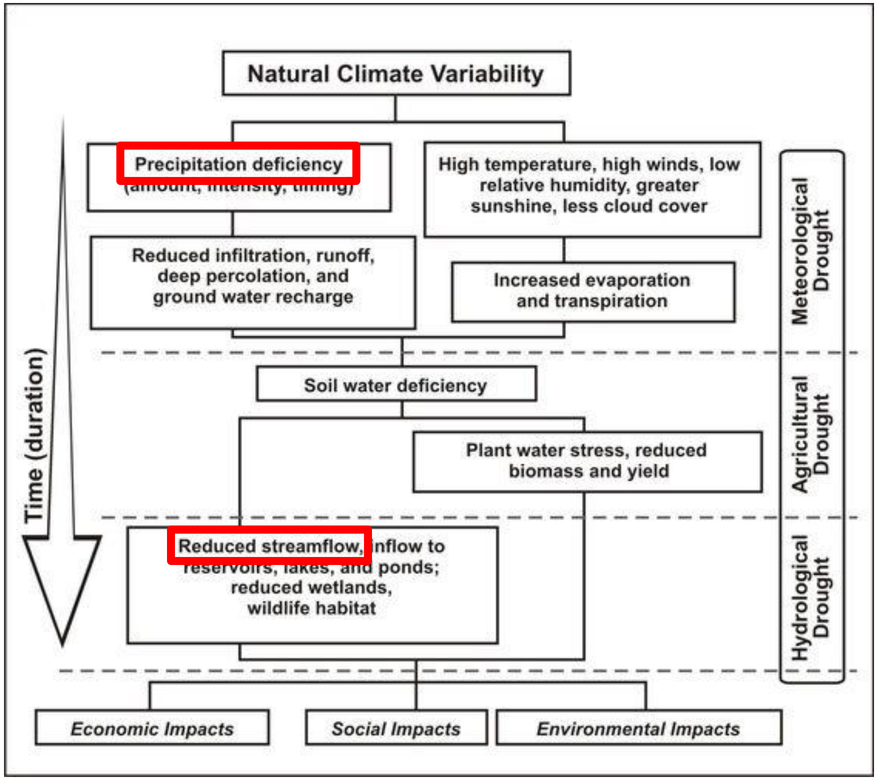
Basel, CH

Drought is an extended period of water shortage affecting different components of the hydrological cycle.



[National Drought Mitigation Center, University of Nebraska – Lincoln, USA, in WMO, 2006]

A **key** major **difference** between **precipitation**/meteorological drought and **streamflow**/hydrological drought events is in the temporal nature of the two variables:

Precipitation → intermittent

Streamflow → continuous

Time-aggregated indices (e.g., SPI-like) are not suited for continuous variables.

Rationale

- A hydrological drought index needs to capture the **time-continuous** nature of **streamflow** data and the occurrence of water deficit.
- A monitoring system needs to be regularly updated in **near-real time**, reflecting the latest water deficit conditions.

Research Goals

- To **develop** a low-flow **index** that **exploits** the **daily** outputs of a spatially distributed **hydrological model**.
- To **evaluate** the **reliability** of this index during **past** well-documented hydrological **drought** events.
- To **implement** this index within the modelling framework of the **operational** European Drought Observatory (**EDO**).

Theory

To capture the time-continuous nature of streamflow daily data, the method is developed within the **theory of runs** framework. [Yevjevich, Hydrology Paper:23, 1967]

Step 1 – low flow regime is detected

Low-flow values are defined as: $Q < Q_{95,t}$ $\quad$ $Q_{95,t}$ = daily threshold

$$Q_{95,t} = \inf\{S_t : F_{(S_t)} \geq 0.95\} \quad \text{with} \quad S_t = \bigcup_{y=1}^{n} \bigcup_{j=t-15}^{t+15} Q_{y,j}$$

Step 2 – events are detected

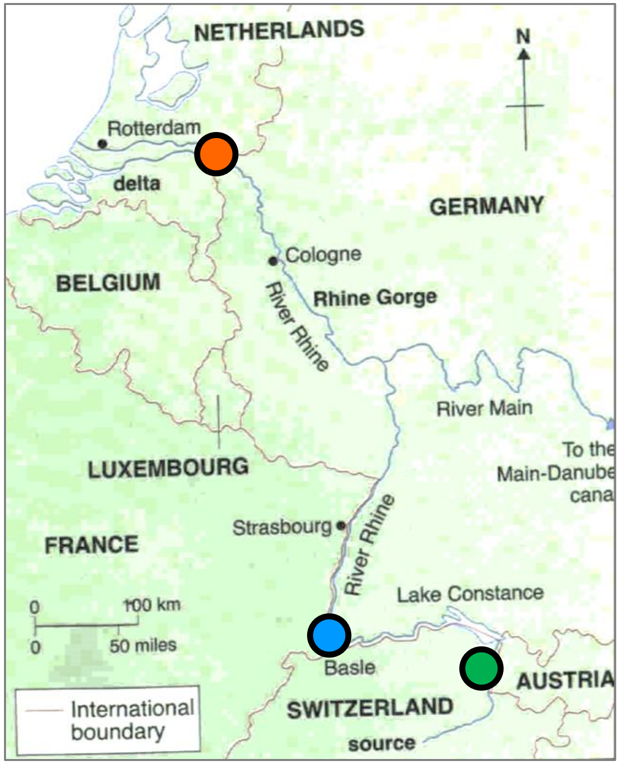
An event is defined (according to the theory of runs) as an unbroken sequence of low-flow values.

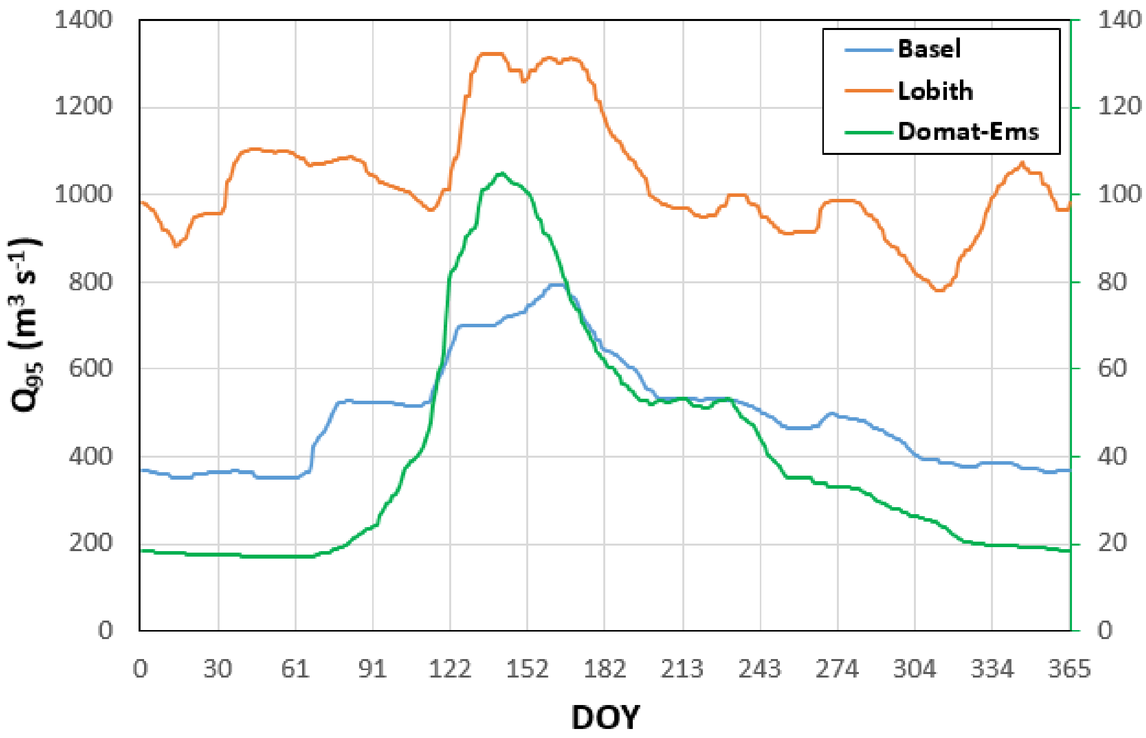
Step 3 – quality check

Minor events (length < 5 days) are removed and close events (gap < 10 days) are pooled. [Zelenhasić and Salvai, WRR:23, 1987]

Step 1

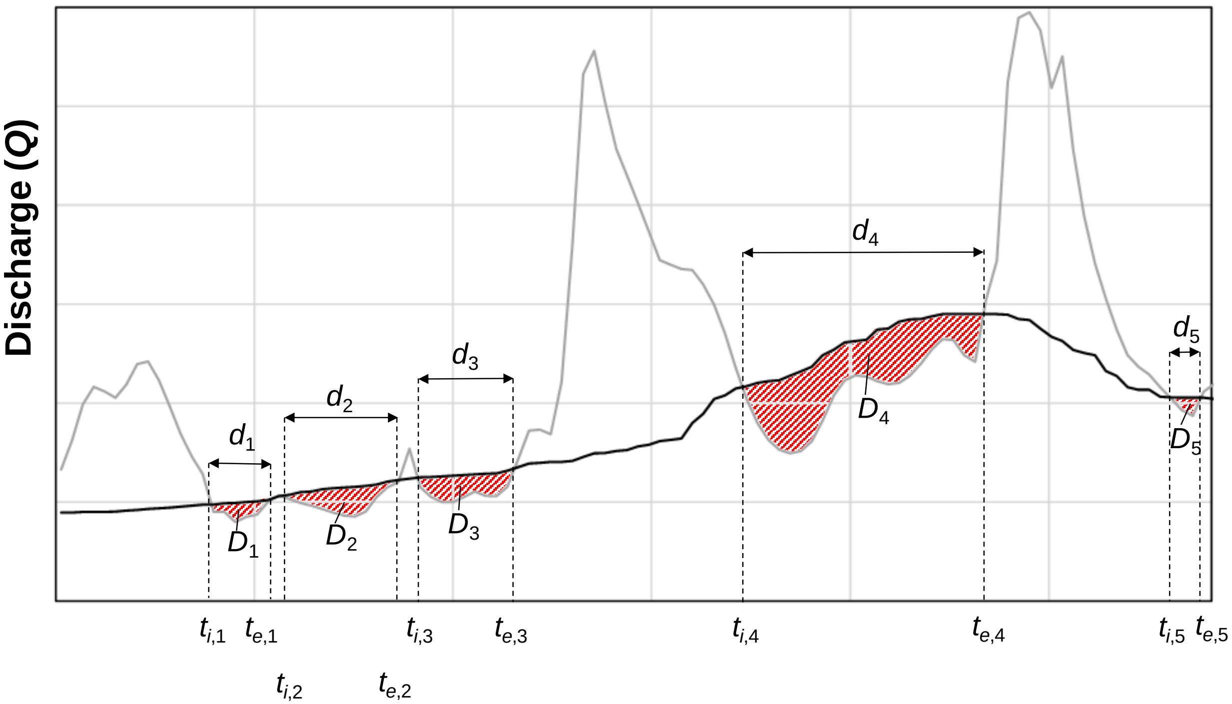
The daily threshold allows capturing different **river water regimes** and possible **seasonality** in low-flow values.





Steps 2 and 3

The events are cumulated on the actual duration rather than on a pre-defined accumulation period (i.e., month).

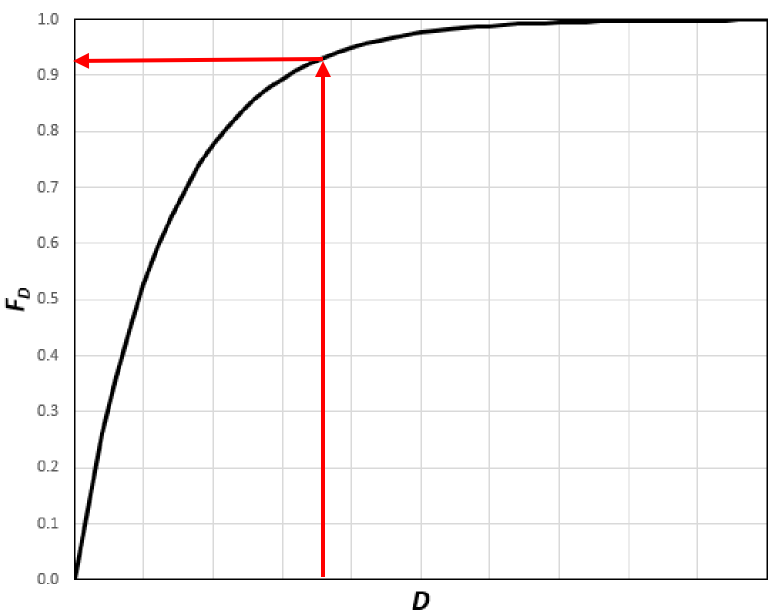


- 5 events are detected accordingly to the theory of runs.
- Events 1-3 are likely dependent, hence pooled into one.
- Event 5 is minor, hence neglected.
- Only 2 "true" events are considered (1+2+3 and 4).

Low-flow index

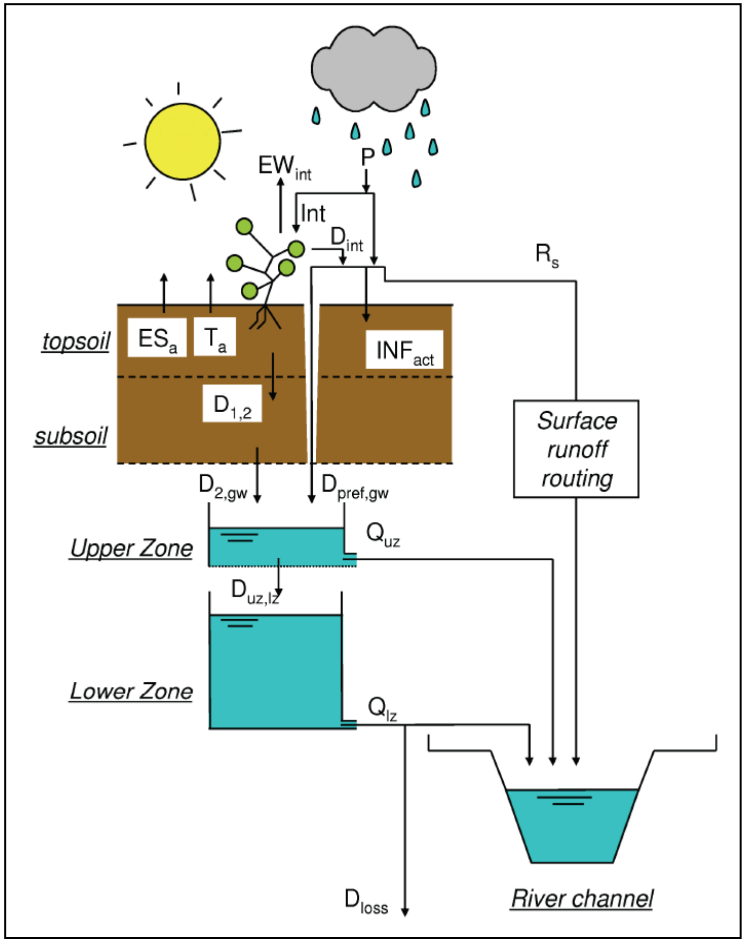
The magnitude of each event is represented by the **Total Water Deficit** (*D*). The frequency of past events is fitted through an exponential distribution.

$$F(D_i;\lambda) = 1 - e^{-\lambda D_i} \quad \text{with} \quad D_i \geq 0$$



- Represents the probability of an event of not being exceeded.
- Is a standardized quantity ranging from 0 to 1.
- Makes comparable events over different regions.
- Does not require a pre-defined aggregation period.

Streamflow dataset for testing



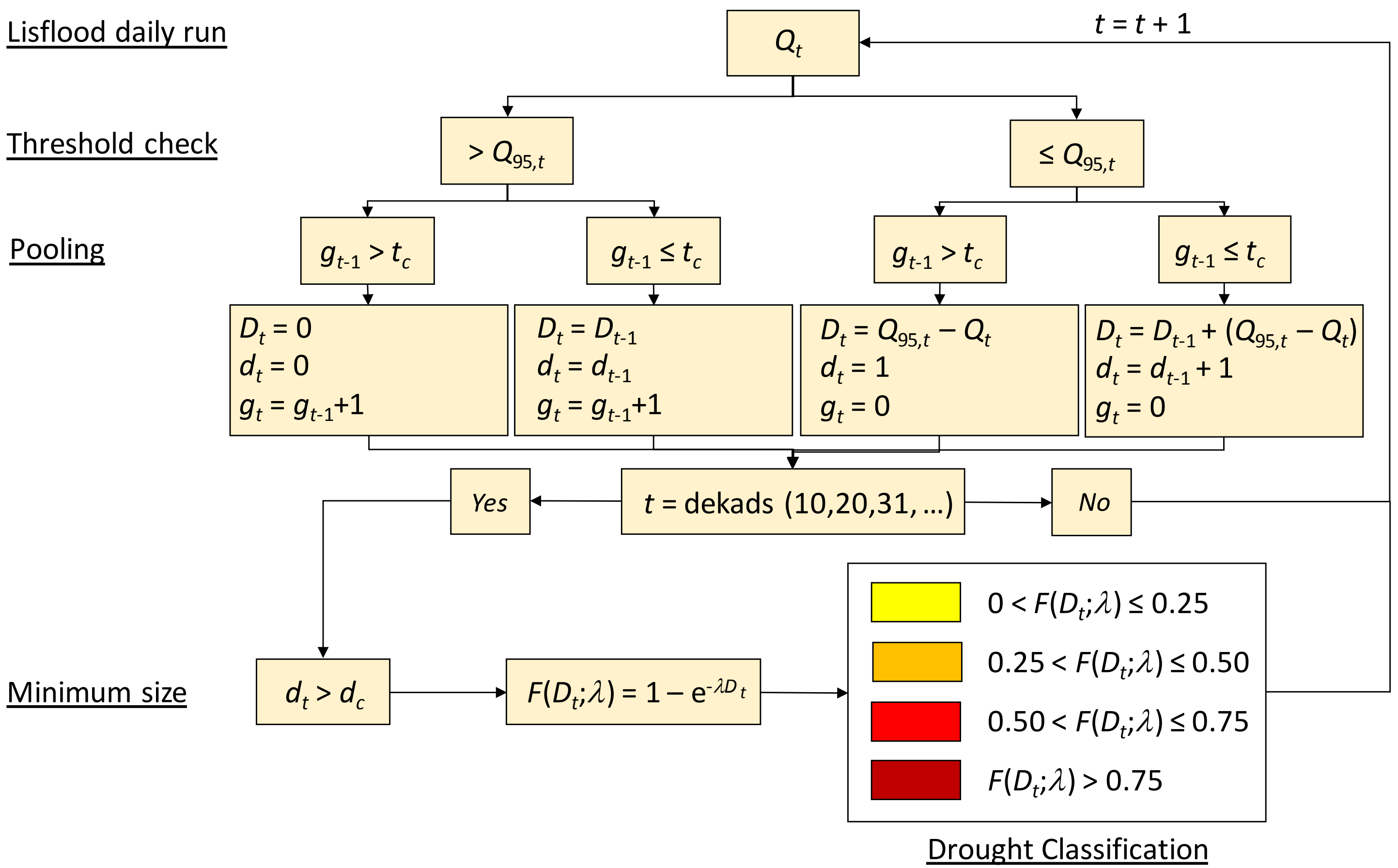
LISFLOOD

de Roo et al. (2000) [Hydrol. Process. 14: 1981-1992]

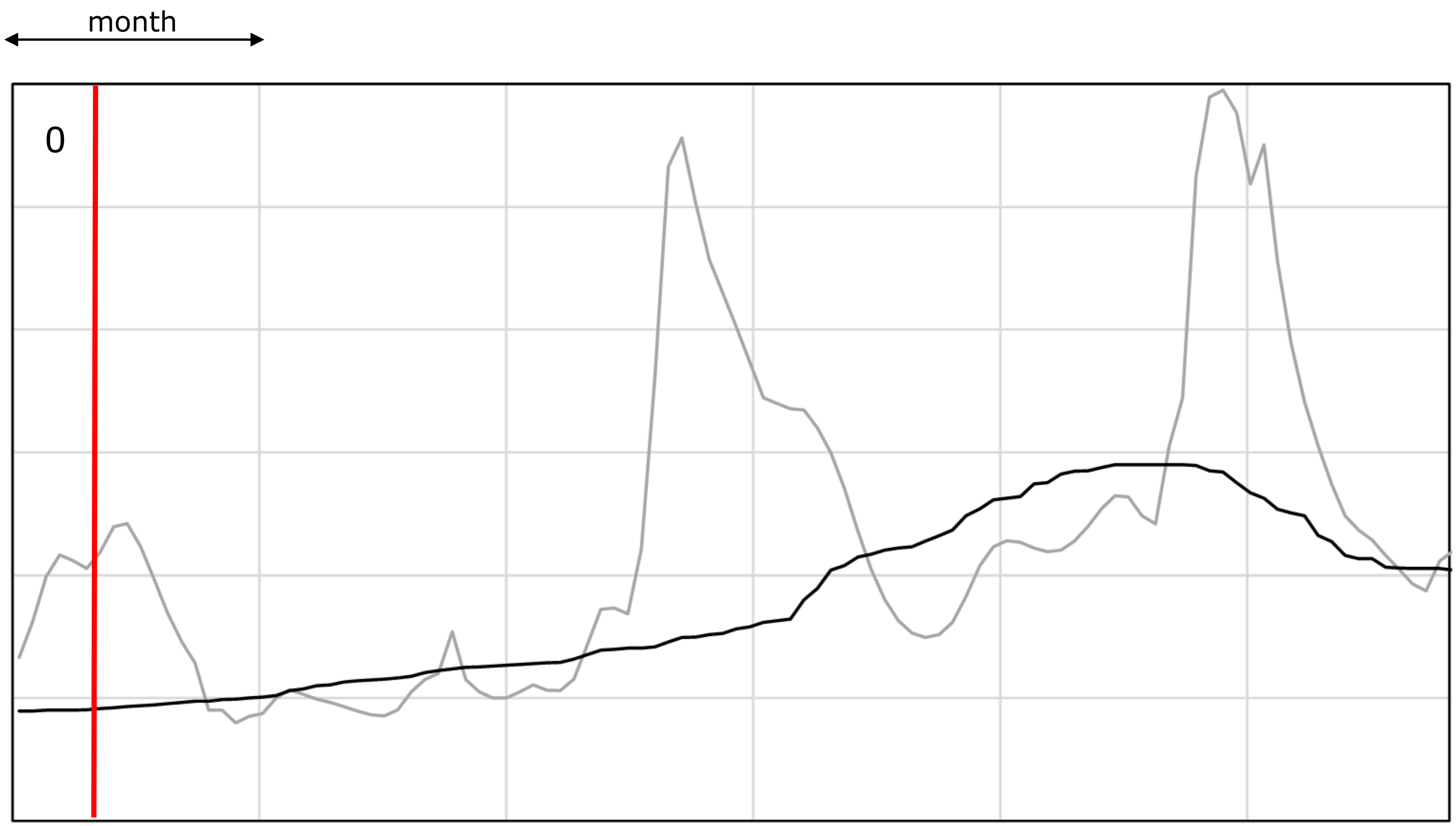
- Precipitation-Runoff model.
- 5-km resolution.
- Daily timestep.
- Hydraulic Soil properties from the European Soil database.
- River network and drainage from 100-m DEM.

- Simulation period: 1995-2015.
- Model calibrated on 693 gauge stations spread across Europe.

Operational Implementation



Example



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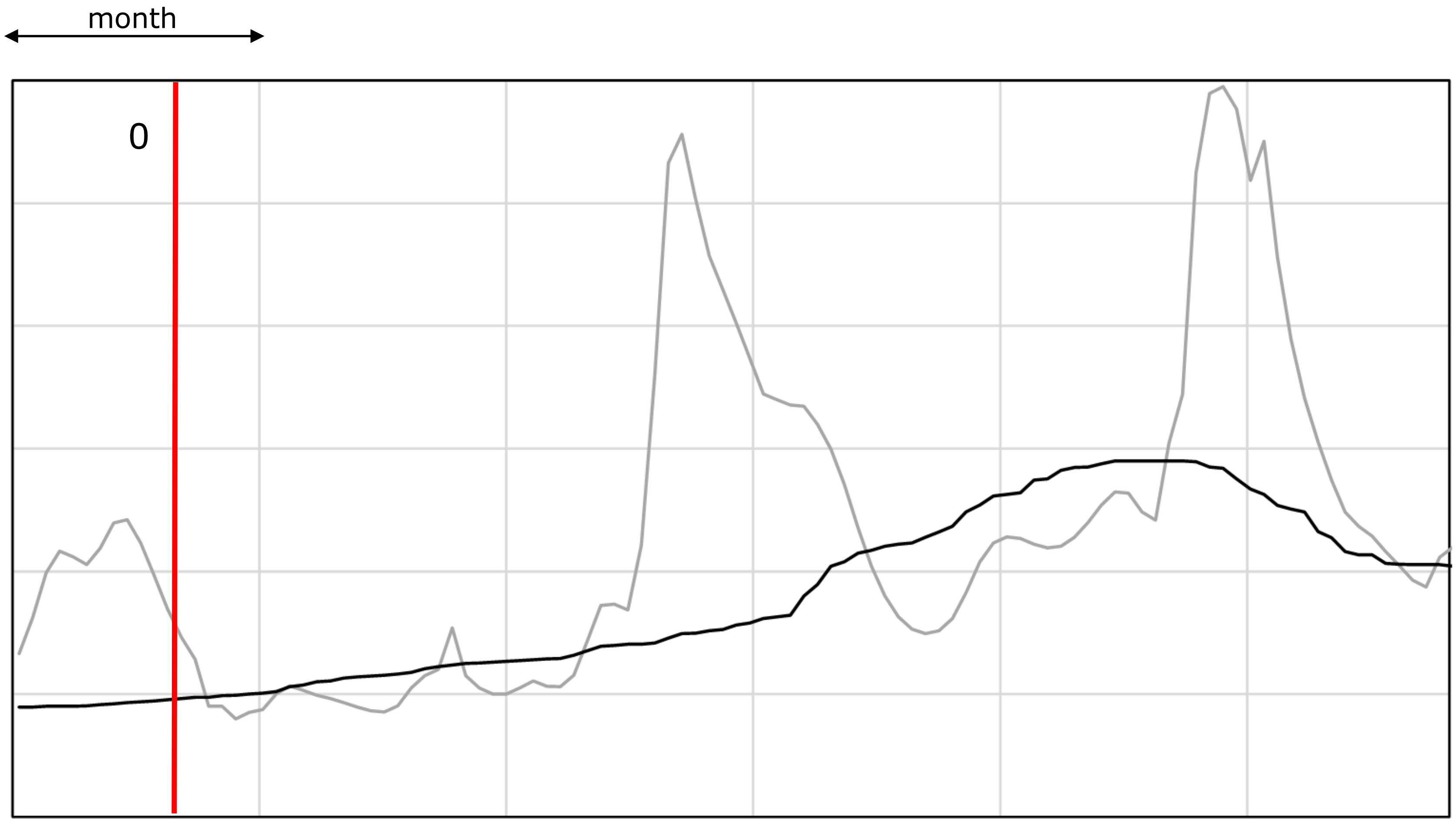

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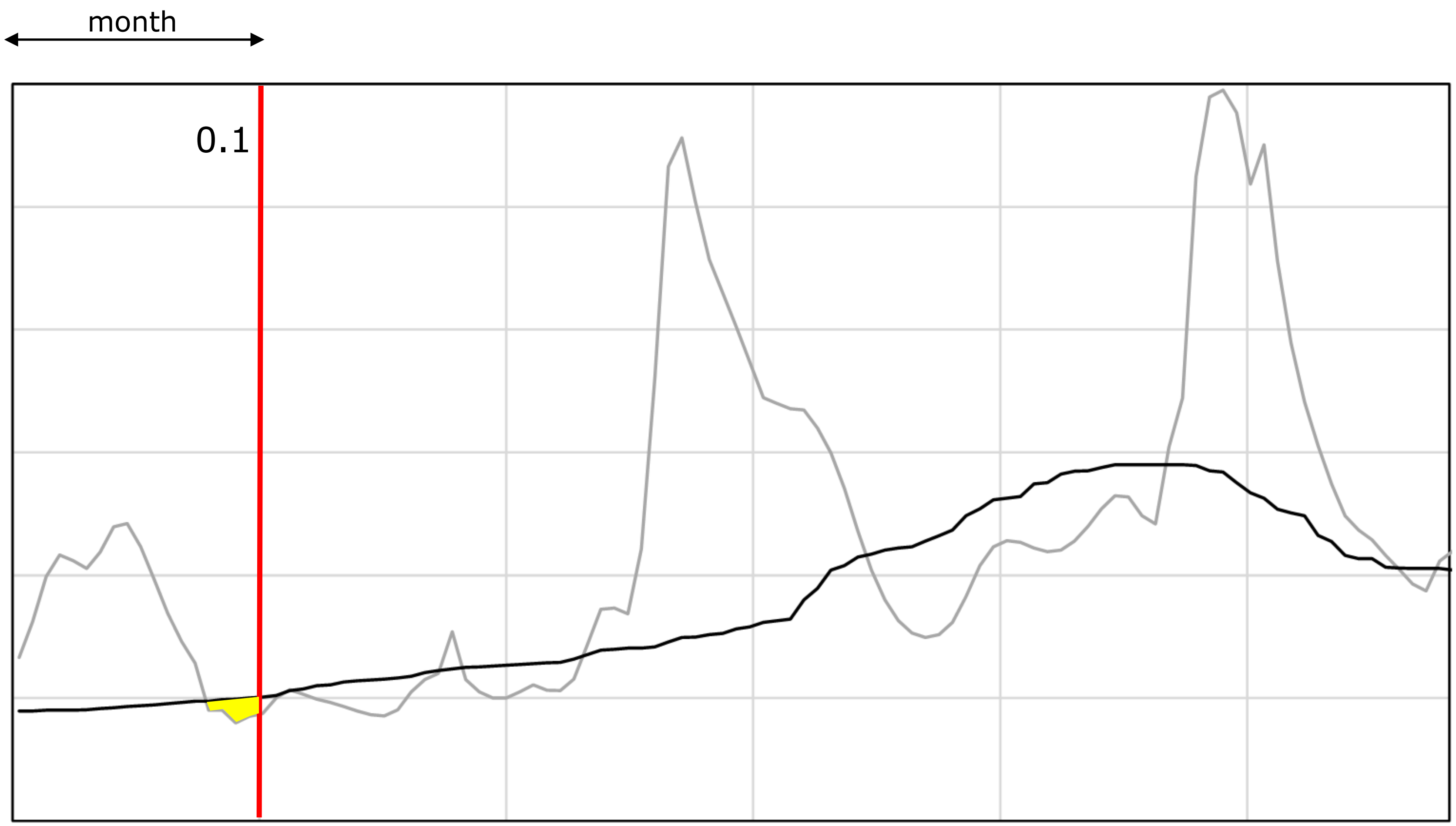

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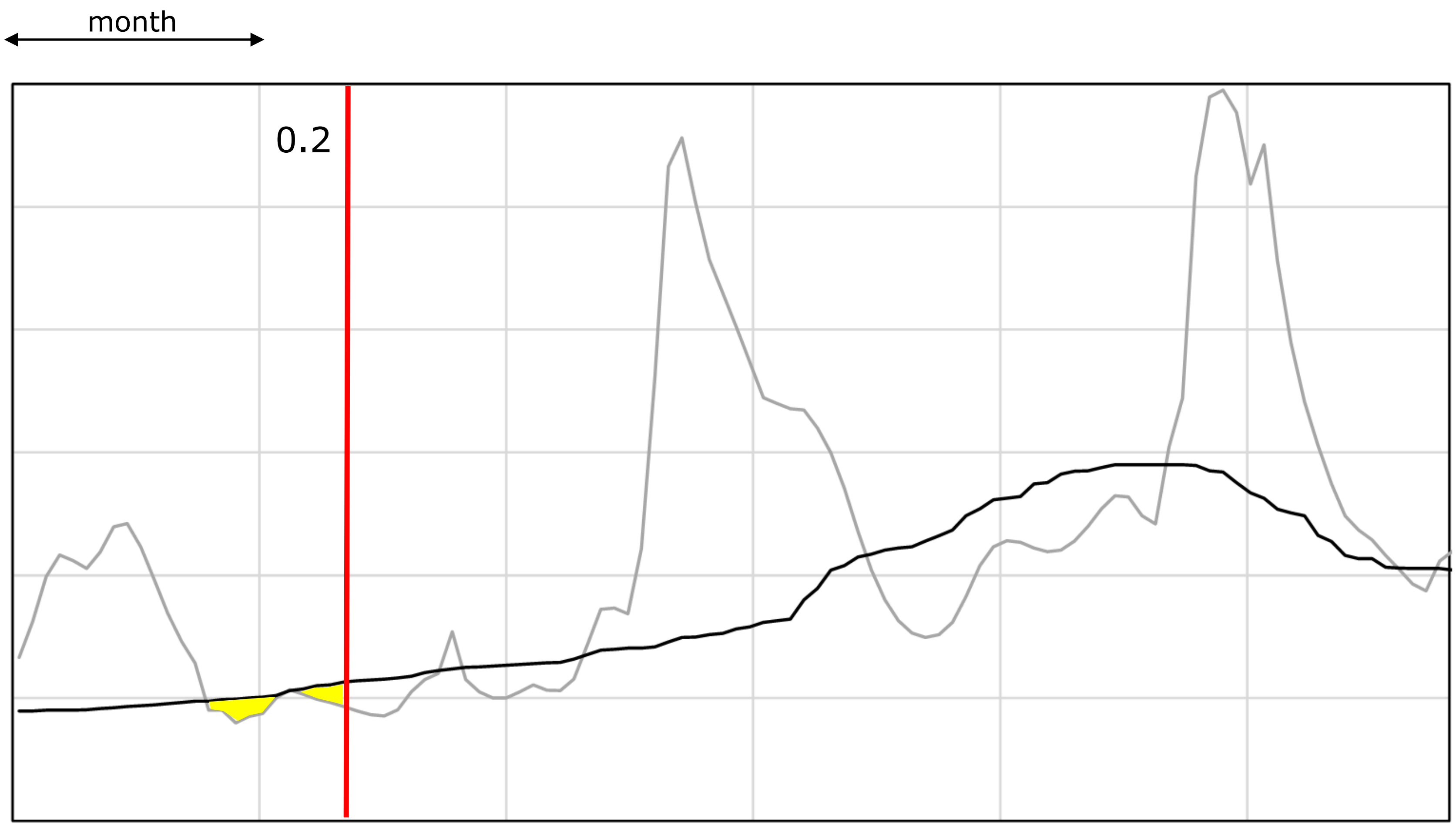

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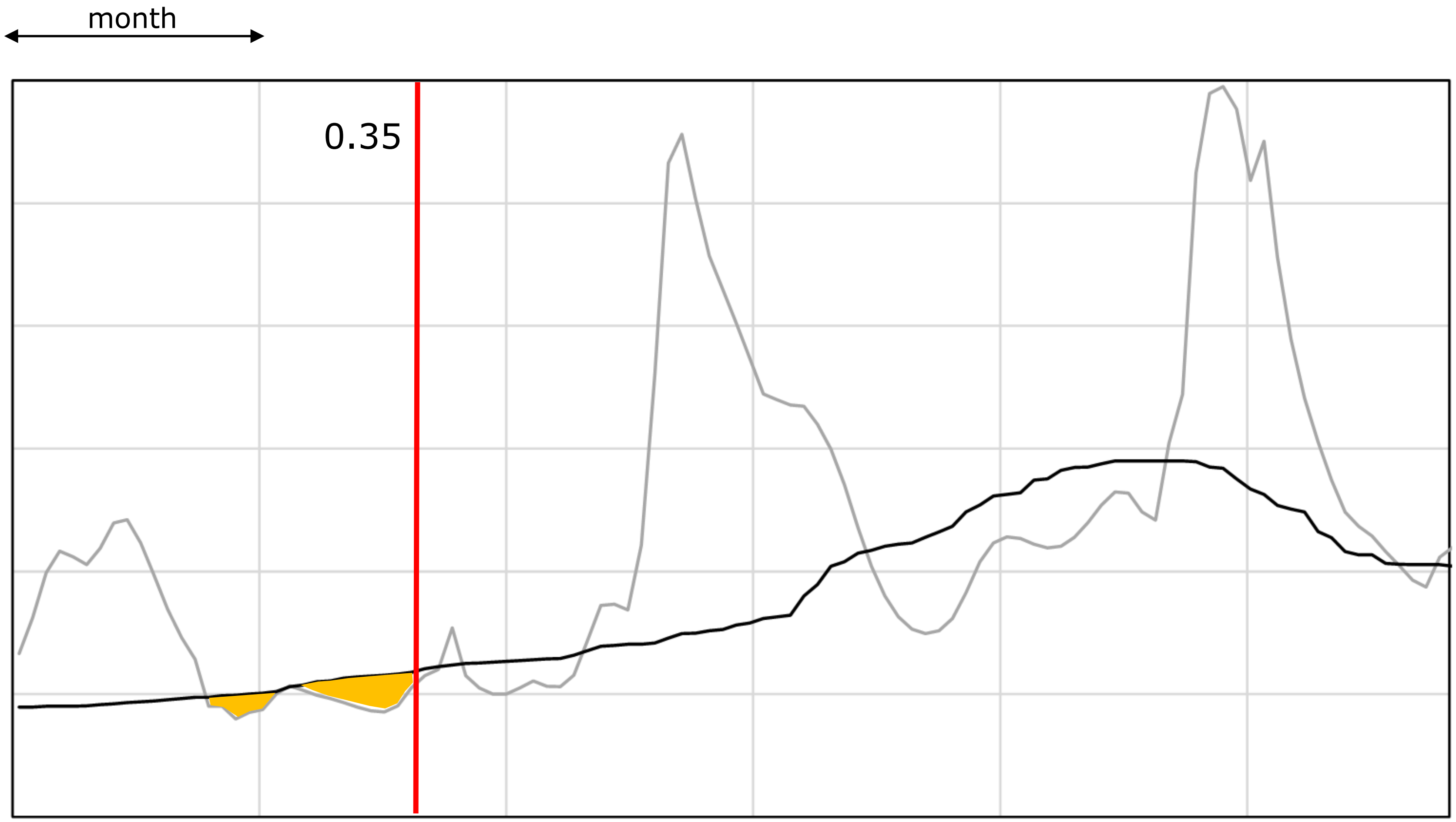

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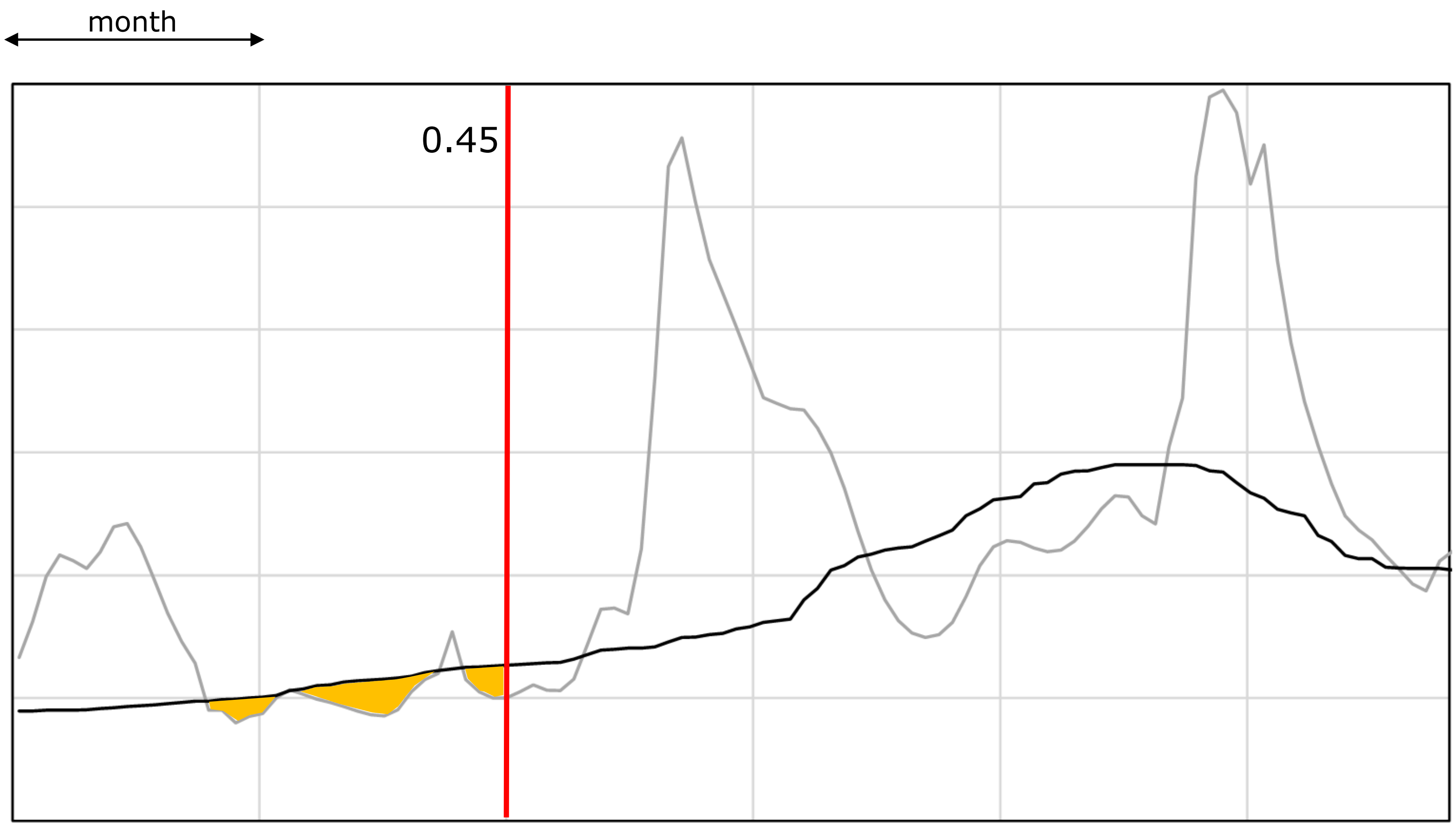

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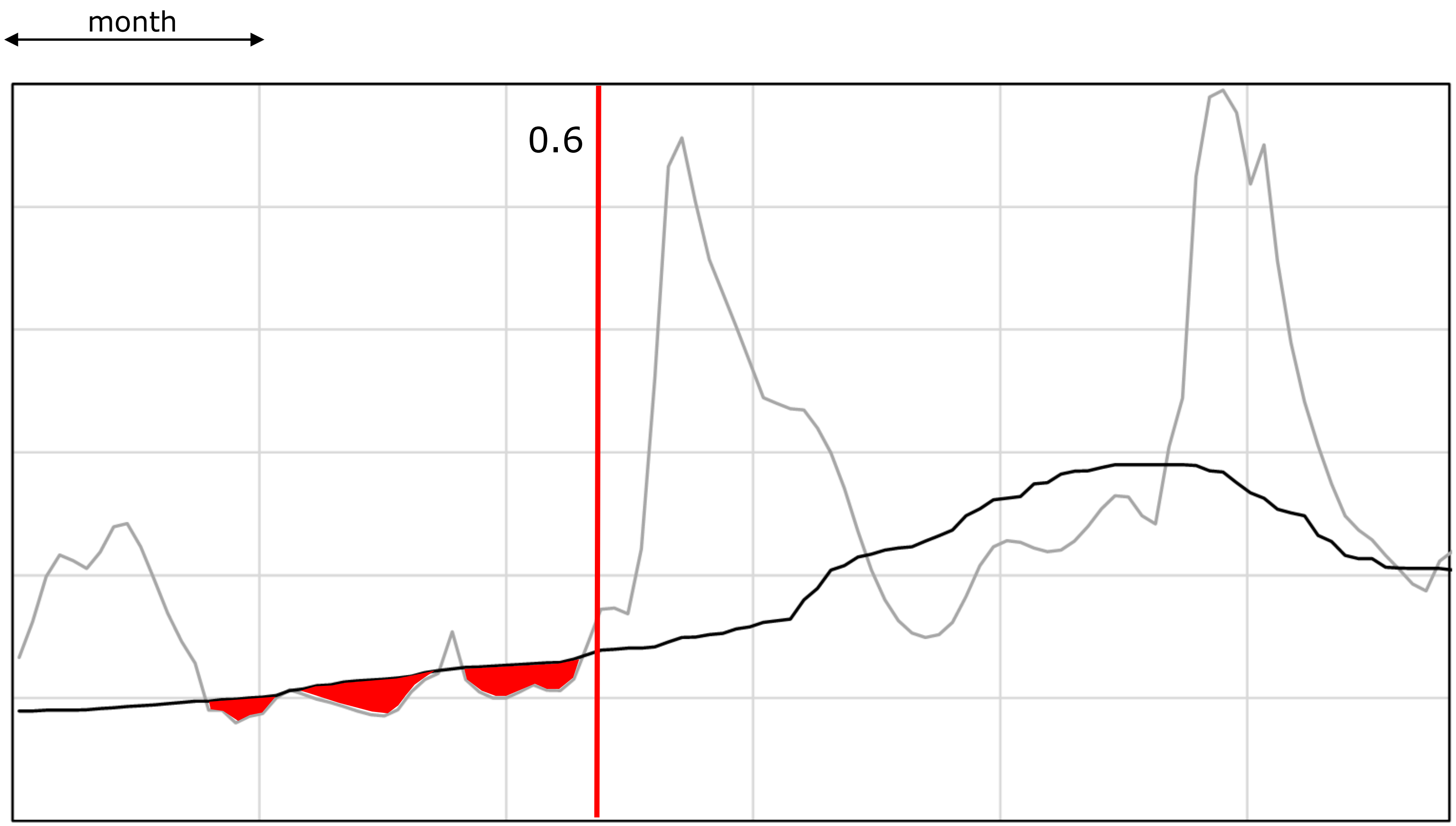
Example



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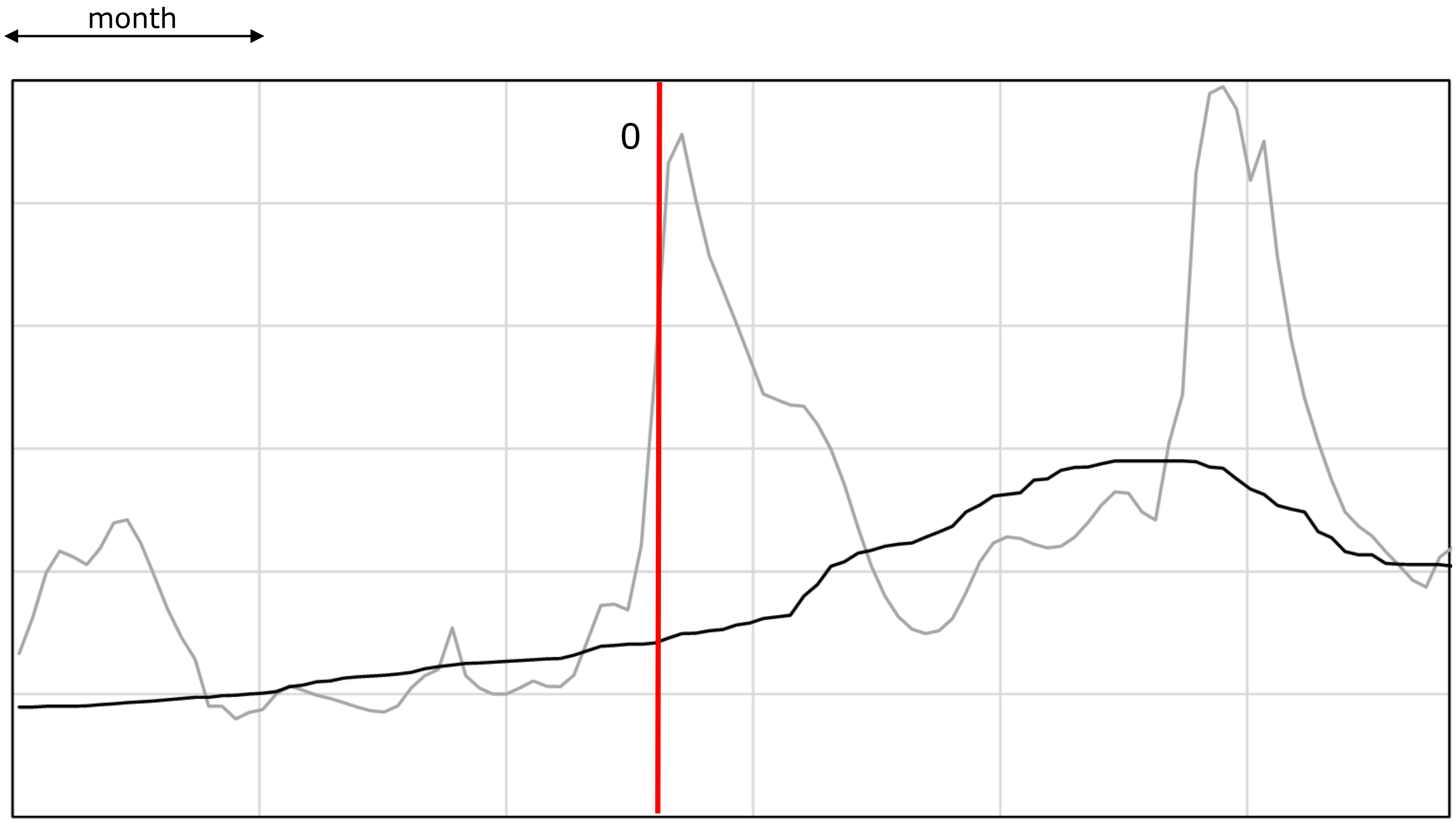

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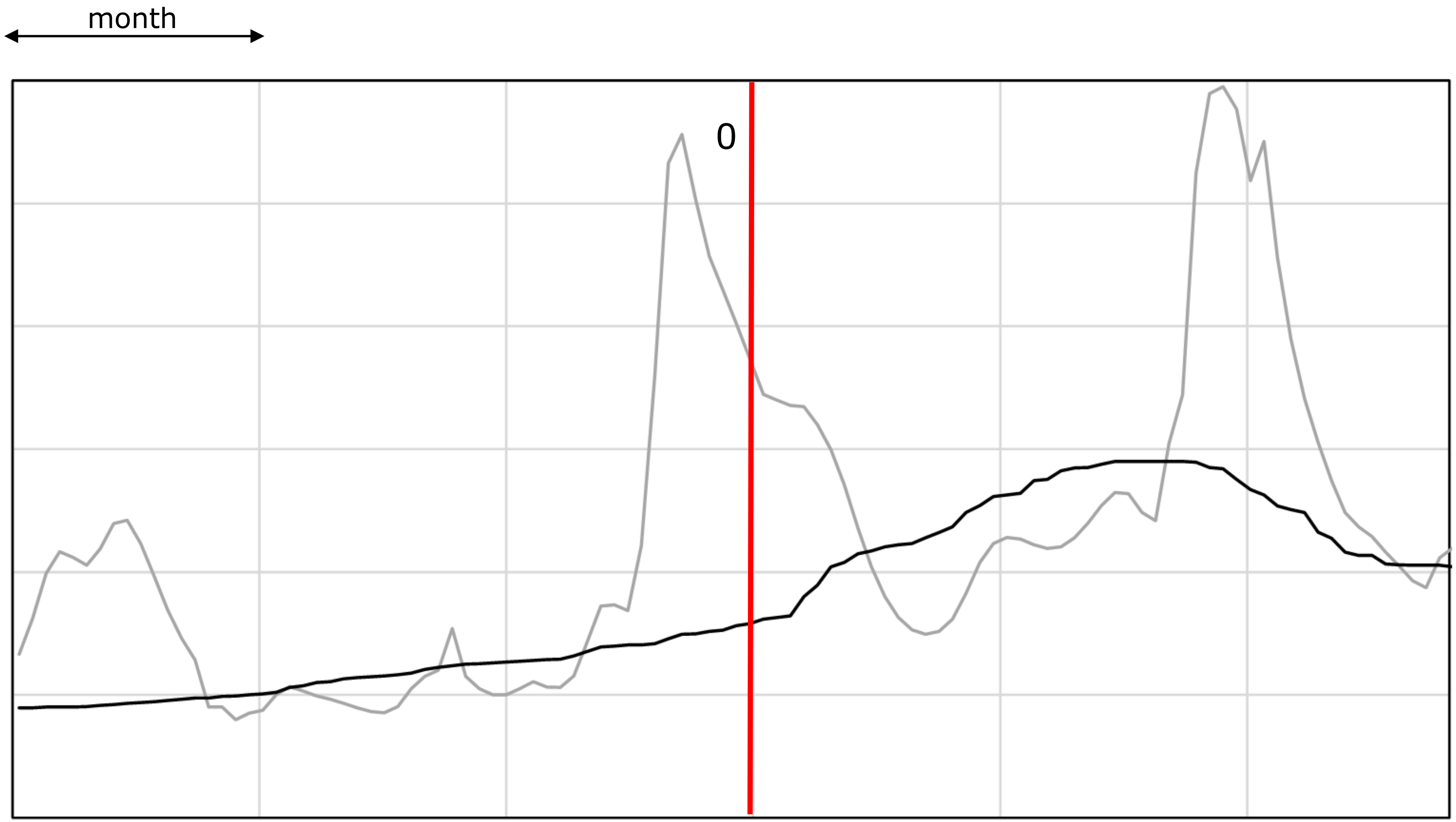

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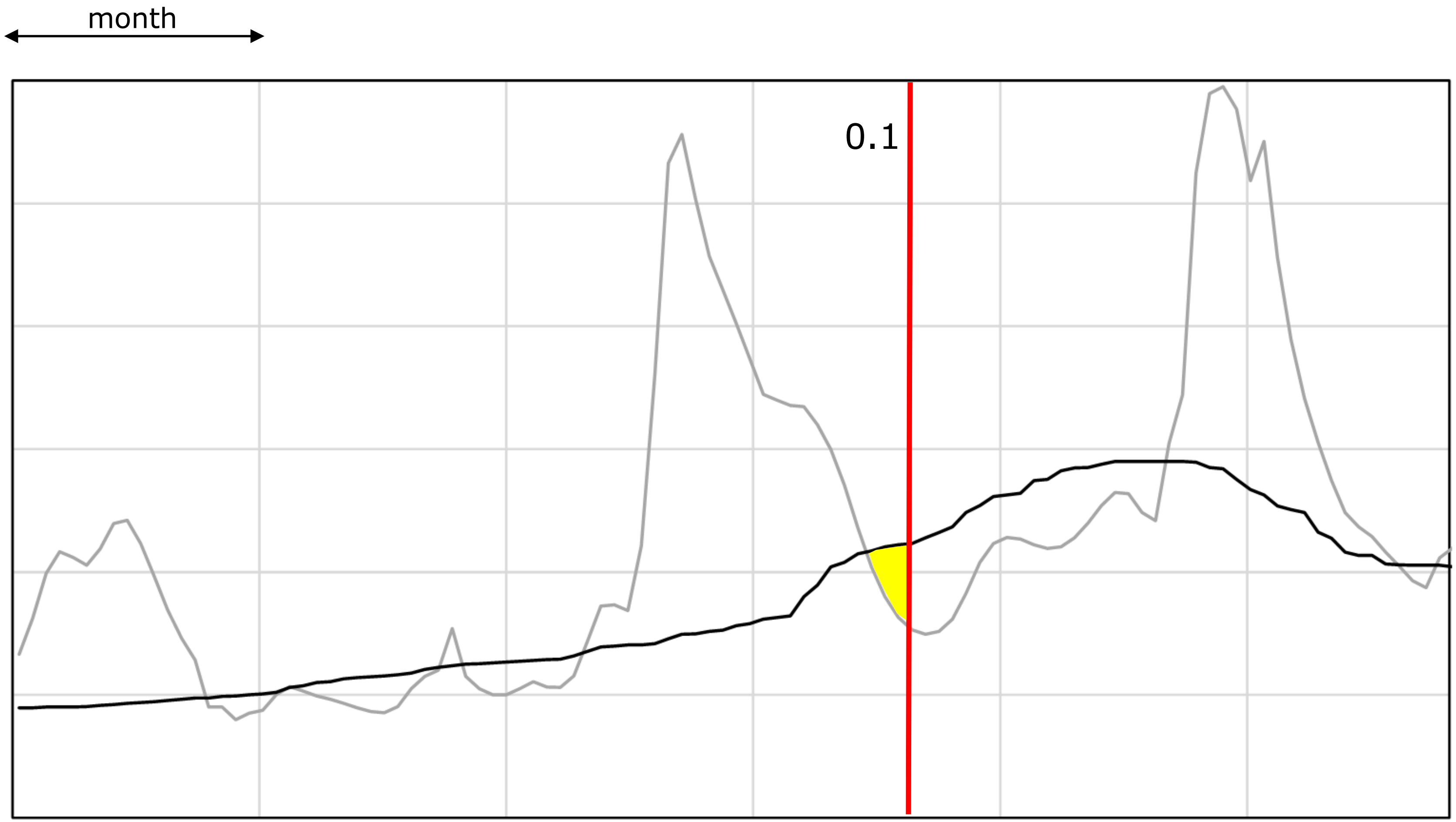

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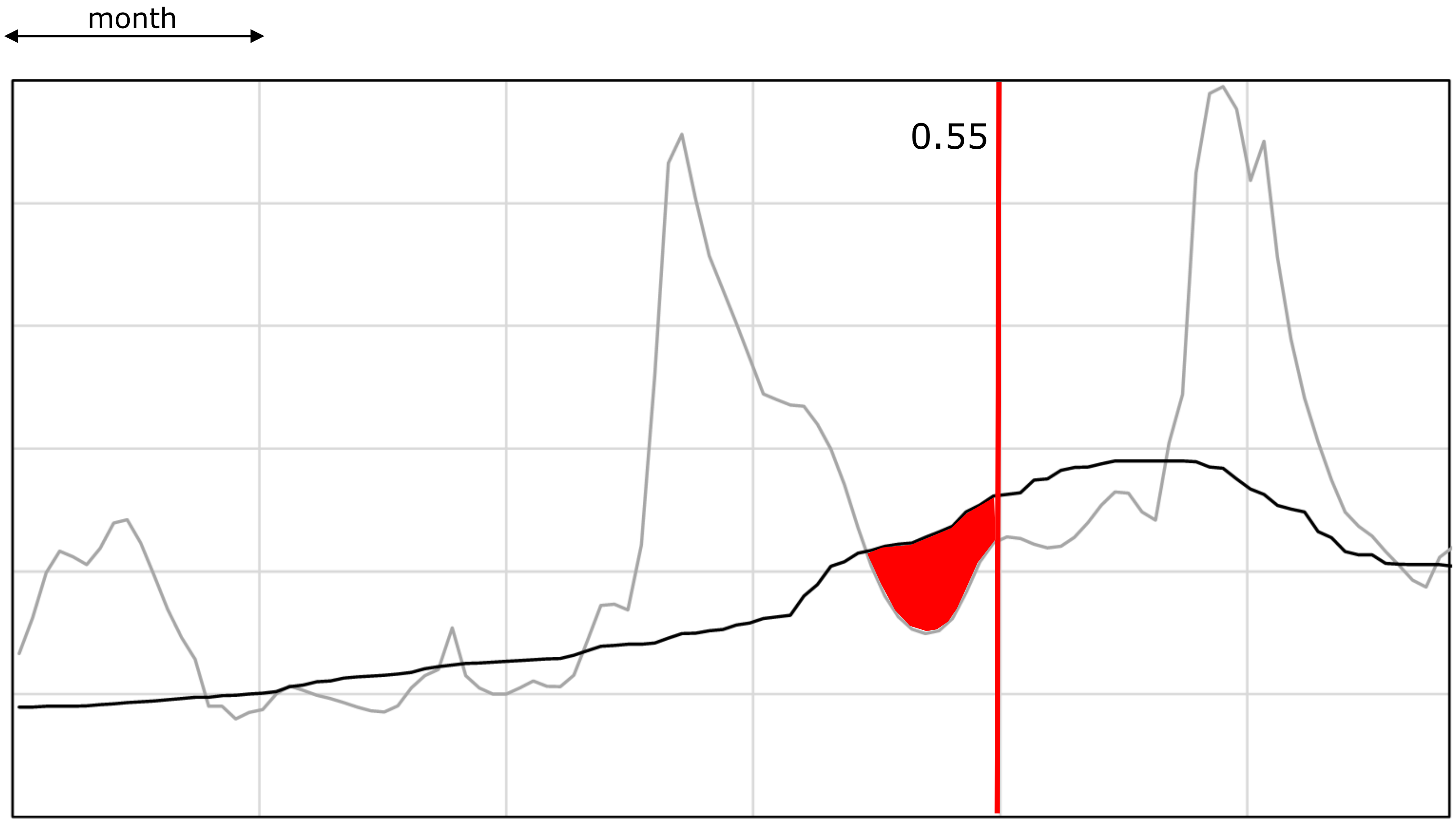

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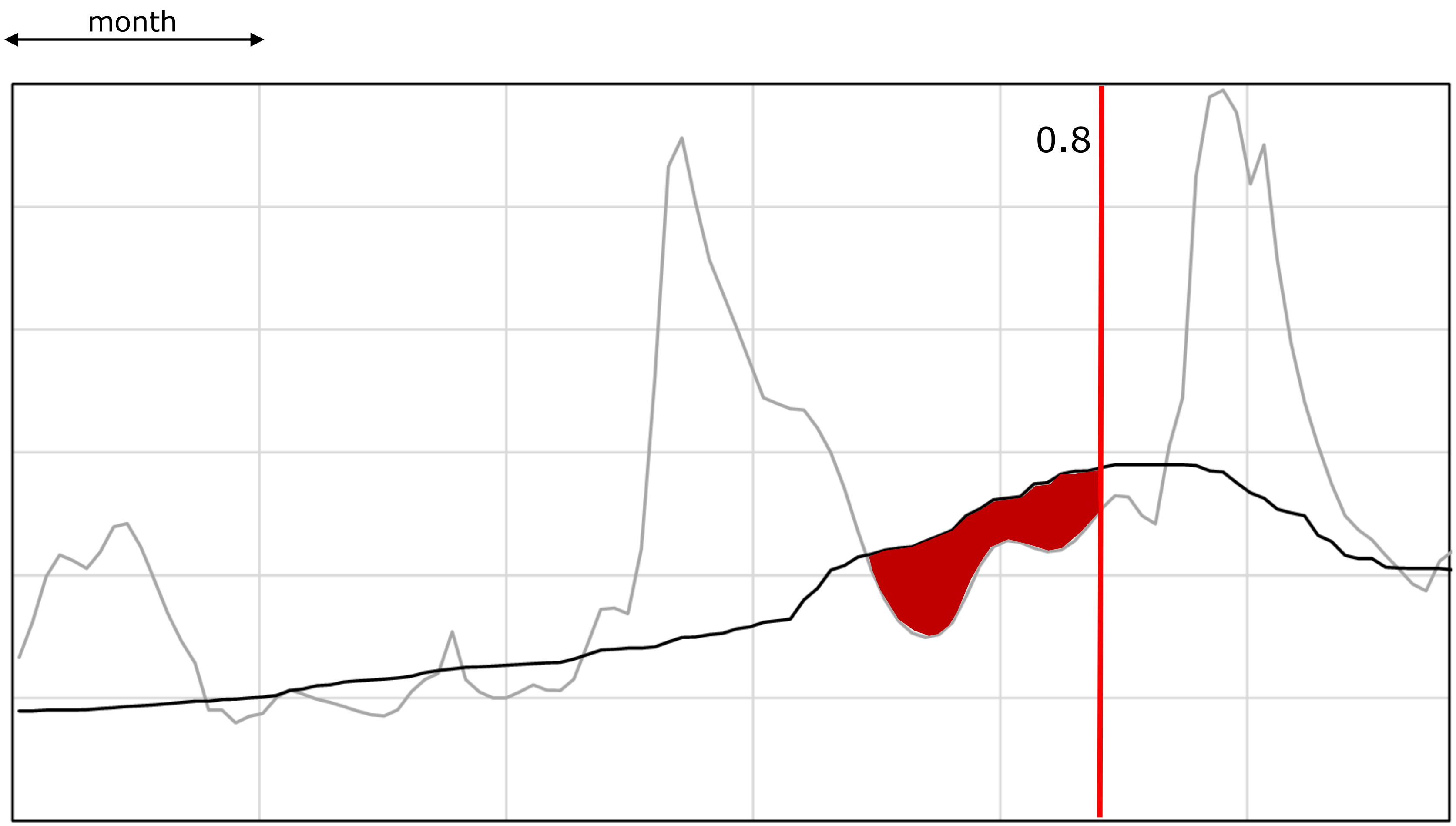
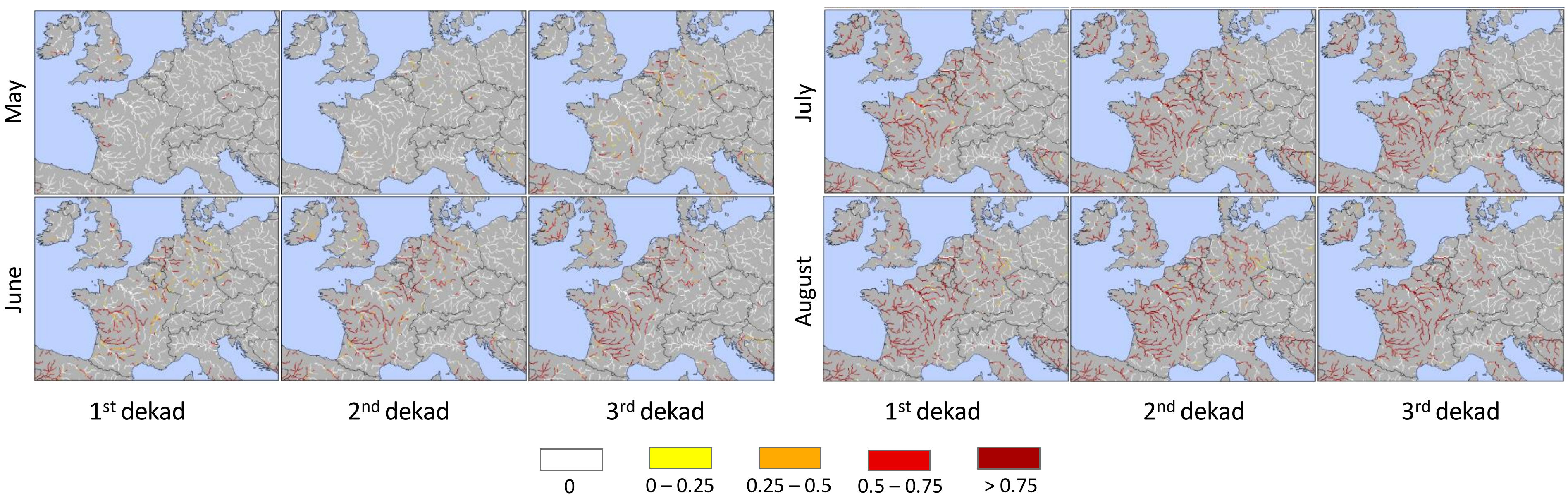


Case Study (1/2)

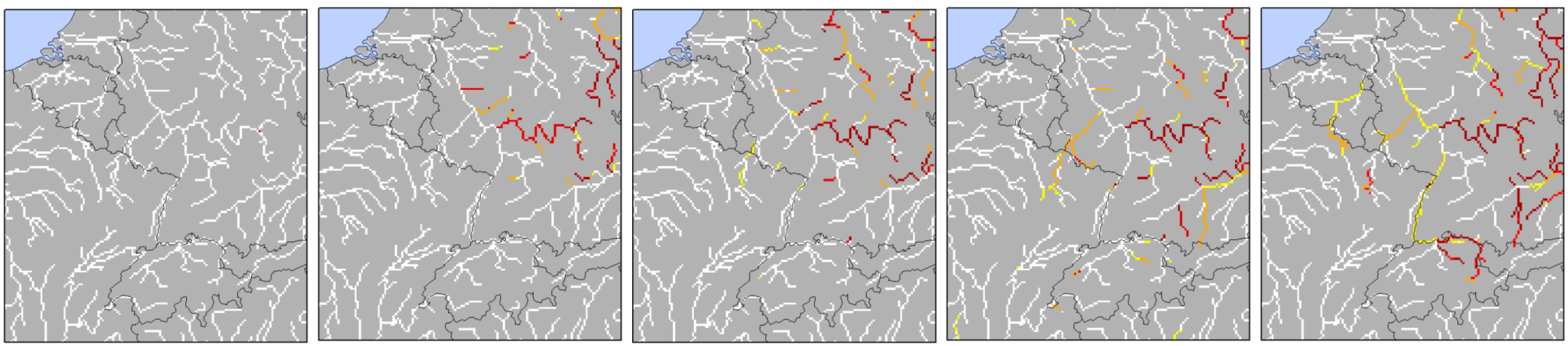
A largely documented drought occurred in Central Europe (mainly France and Germany) during summer 2015.



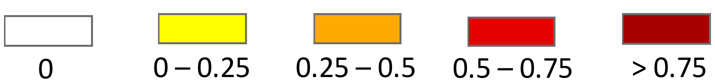
The temporal dynamic of the event seems well captured, starting in June and reaching the maximum in July-August. Also the spatial patterns seem reliable.

Case Study (2/2)

A largely documented drought occurred in Central Europe (mainly France and Germany) during summer 2015.



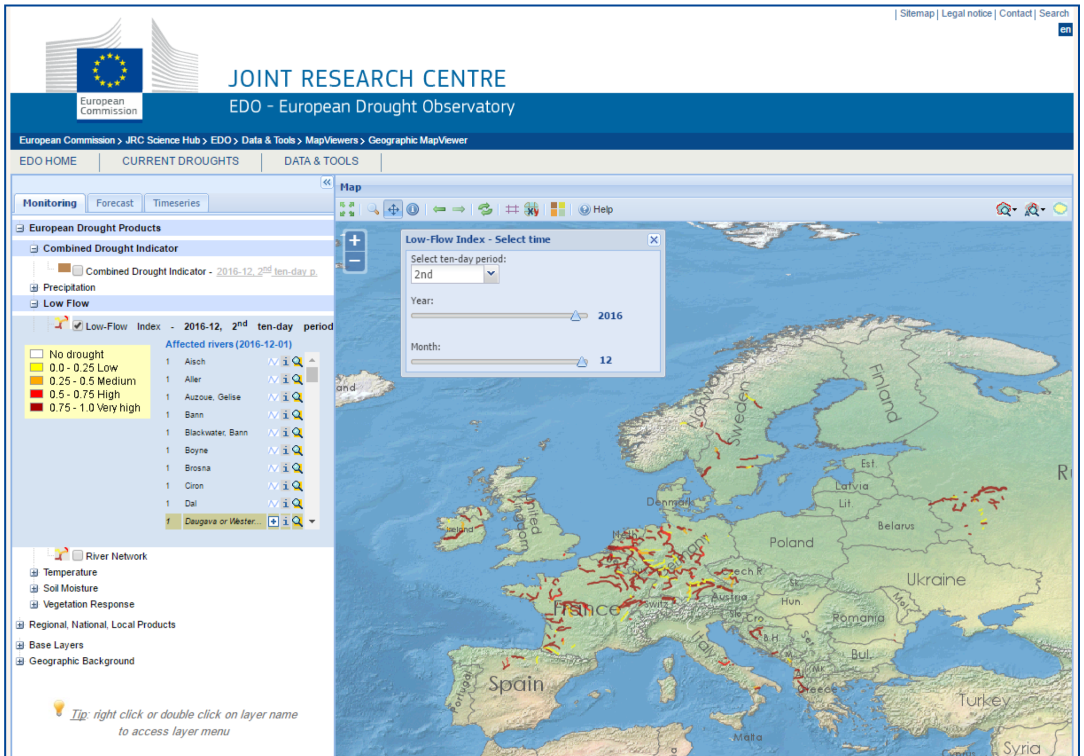
1-10 May | 1-10 June | 1-10 July | 11-21 July | 11-21 August



In the Rhine the drought seems to start on the German side in June and it followed by a fast decline on the France side in July. Almost the full river is effected in the middle of August.

Implementation in EDO

The index is currently available in near-real time in the EDO system. Maps are updated every dekad, with approximately 2 days of delay.



- Only cells with upstream **drainage > 1,000 km²** are reported.
- Spatial distribution of F_D can be visualized in the *map viewer*.
- River **segments** are mapped al lower scale.
- **Single cell** values are visualized at higher scale (> 1:1,250,000).
- A list of the rivers affected is also reported on the left.

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Summary and Remarks

- A novel **hydrological drought index** is proposed, which takes into account the temporal-**continuous** nature of **streamflow** data.
- The proposed index fully **exploits daily** long-term **records** to define the low-flow river regime (95th percentile).
- The approach **avoids** the need of a **pre-defined accumulation** period (i.e., month), allowing long events across different consecutive months.
- **Consistency** between the JRC **EDO** and the **EFAS** (flood monitoring) systems is ensured by the **use** of the same **Lisflood**-based river discharge datasets.
- The index has been successfully **implemented** into operational **EDO** since early **2017**.

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