Space-Time Dynamics of Extreme Floods

Evaporative moisture sources of Vb-floods during the 20th century

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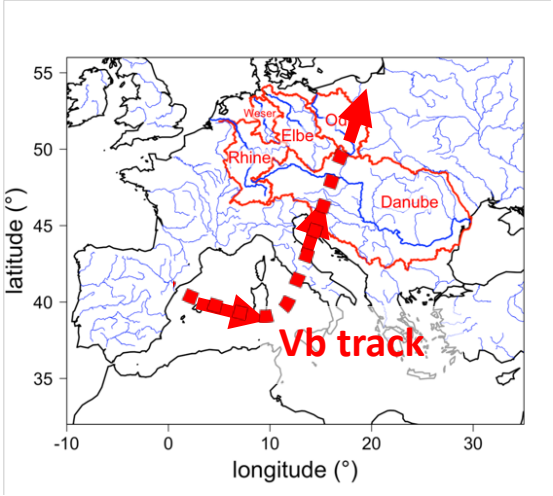
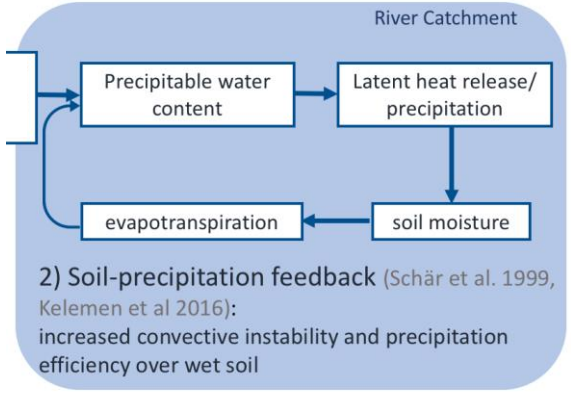
Please leave a comment or contact Amelie Krug ✉ if you have any questions.

Key results:

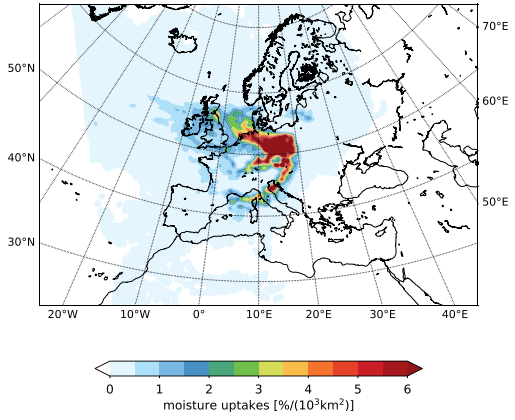
1) Most severe summer floods in Central Europe during 1901 – 2010 were associated with so-called Vb-cyclones.



2) Continental moisture source regions highlight the importance of soil-precipitation feedback.



3) Interestingly, Lagrangian diagnostics point towards equally important contributions from the Mediterranean Sea as from the North Atlantic, the North Sea and the Baltic Sea.



Research questions

About **5 Vb-cyclones** occur on average **per year**. However, only a few Vb-cyclones cause extreme summer floods. This raises the following questions:

What makes an Vb-flood event extreme?

In particular, what intensifies Vb-cyclones causing extreme floods during **summer**?

State of the art: What intensifies Vb-events during **summer**?

- In fact, the **80th percentile of maximum relative vorticity** is **larger** for summer Vb-cyclones compared to winter North Atlantic cyclones (Hofstätter et al., 2016).

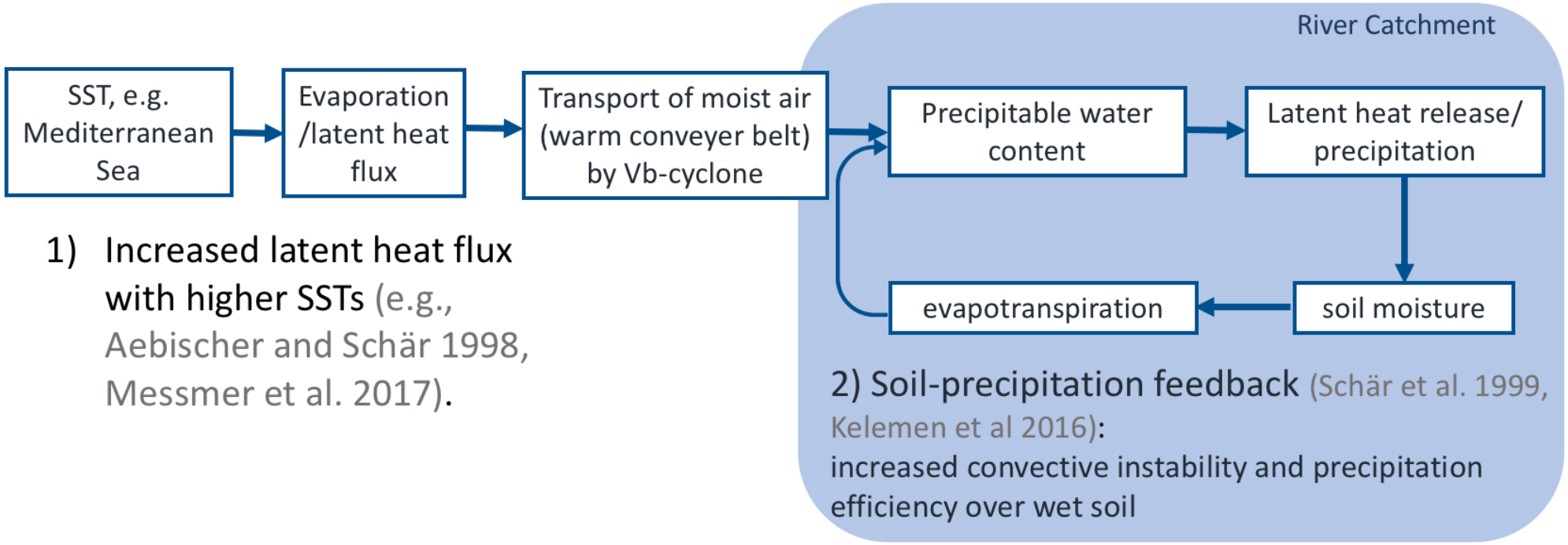
- During summer, an essential ingredient for intense Vb-events **are high equivalent potential temperatures** and **thus latent heat release** in lower levels over northern Italy (Aebischer and Schär , 1998).

- This is supported by the sensitivity study of Messmer et al. (2017) which showed more intense cyclones with **increasing sea surface temperatures** (SSTs) of the **Mediterranean Sea**.

- Furthermore, higher temperatures during summer **increase the total water content** and moisture transport in the atmosphere, together with a **decreasing atmospheric stability** (Messmer et al. , 2017).

- In addition, **continental evaporation** and the **North Atlantic ocean** contribute to flood producing heavy precipitation (e.g. May/June 2013 flood, Kelemen et al 2016).

Hypothesis: Vb-cyclone intensification due to…



1) Increased latent heat flux with higher SSTs (e.g., Aebischer and Schär 1998, Messmer et al. 2017).

2) Soil-precipitation feedback (Schär et al. 1999, Kelemen et al 2016):
increased convective instability and precipitation efficiency over wet soil

So far, the moisture source regions have been analysed only for selected Vb-floods
(August 2002: Gangoiti et al., 2011; Sodemann et al., 2009; James et al., 2004; Gangoiti et al., 2015, August 2005: Winschall 2013, May 2010: Winschall et al., 2014, and May/June 2013: Kelemen et al., 2016; Grams et al., 2014; Schröter et al., 2015).

→ We extend the abovementioned **case studies** and analyse the **processes intensifying Vb-cyclones** based on a **climatology** of Vb-events during **1901-2010**.

Data basis: Centennial Simulation

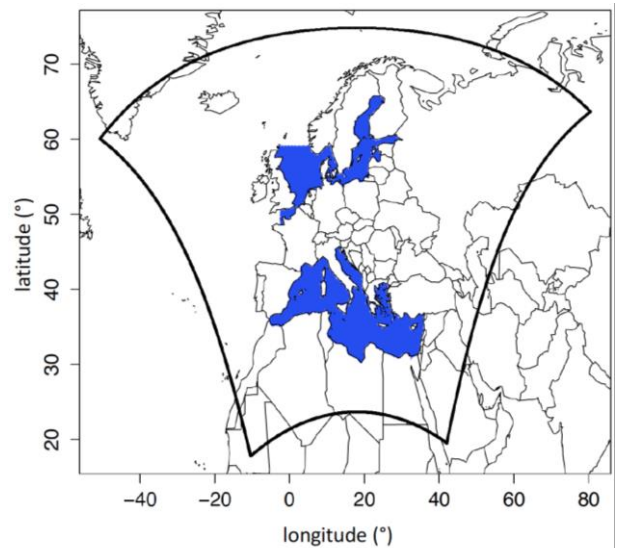
Dynamically downscaling of centennial reanalysis (Kelemen et. al 2019, Primo et al. 2019) with a high resolution and interactively coupled atmosphere-ocean model setup to…

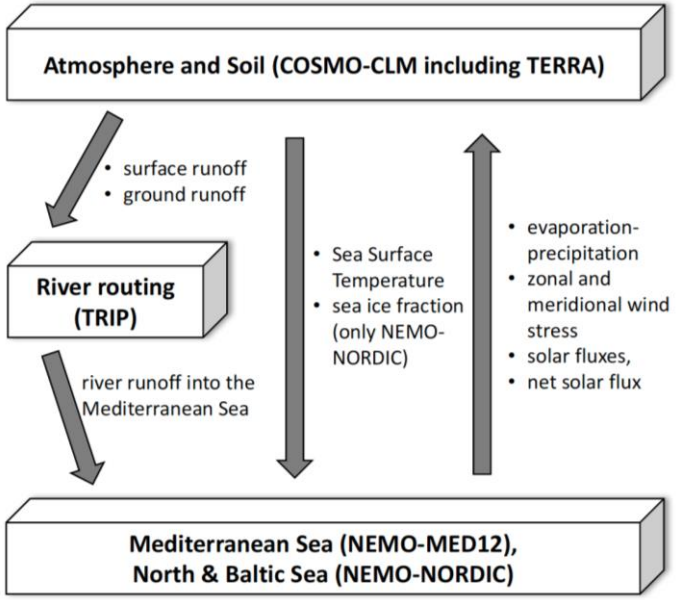
… improve the spatial scale (e.g. influence of orography on heavy rainfall)

… better represent the components of the water cycle

… study extreme events which requires long time series

Driving data:	ERA-20C
Time period:	1901-2010
Coupled regional models:	COSMO-CLM+NEMO-MED+NEMO-Baltic+TRIP
Horizontal resolution:	0.11°

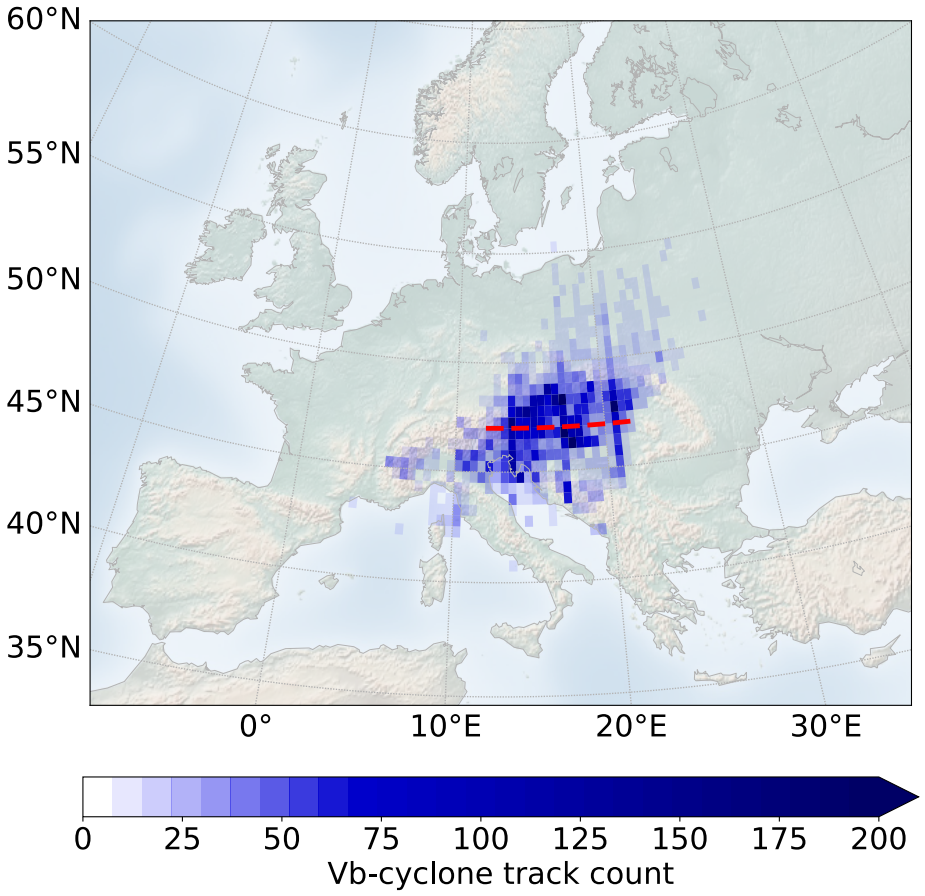




Methods: Cyclone tracking

We tracked all cyclones in our dynamically downscaled reanalysis from 1901 to 2010 with the tool of Wernli and Schwierz (2006).

All cyclones crossing the latitude 47°N between 12°E and 22°E northeastwards were classified as Vb-cyclones (cf. Hofstätter and Blöschl, 2019). In total, 1107 Vb-cyclones were detected during 1901-2010.



Methods: moisture uptake calculation with Lagranto + WaterSip

1. We defined a four-day period of heavy rainfall for selected extreme Vb-floods.
2. We calculated the hourly backward trajectories in our dynamically downscaled ERA-20C reanalysis with Lagranto (Wernli and Davies 1997, Sprenger and Wernli 2015) for the Danube, Elbe, and Odra catchment (Fig., black rectangles).
3. These trajectories were used as input for the moisture uptake calculation following Sodemann et al. (2008, ”WaterSip”).

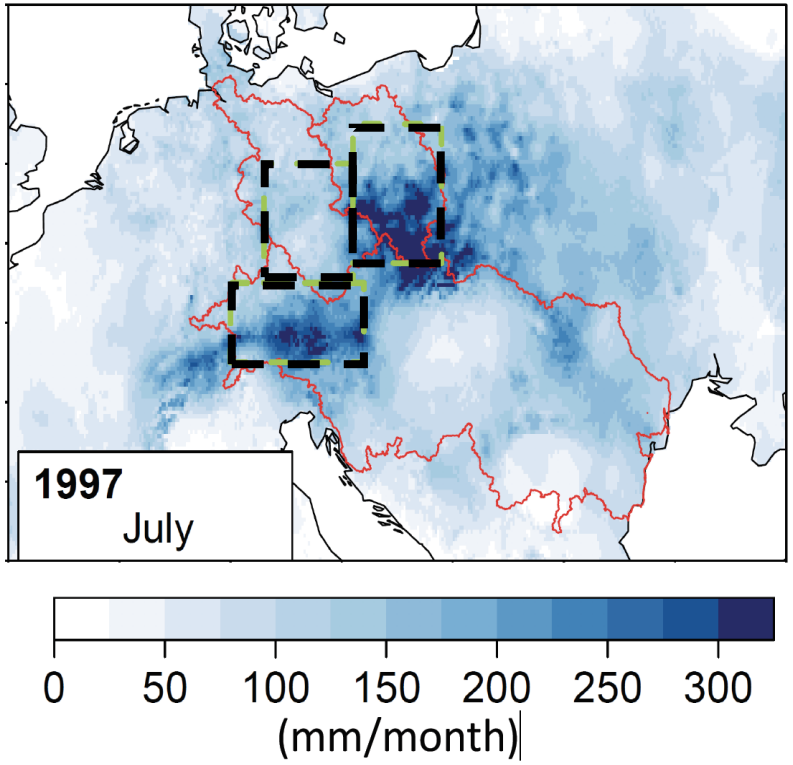
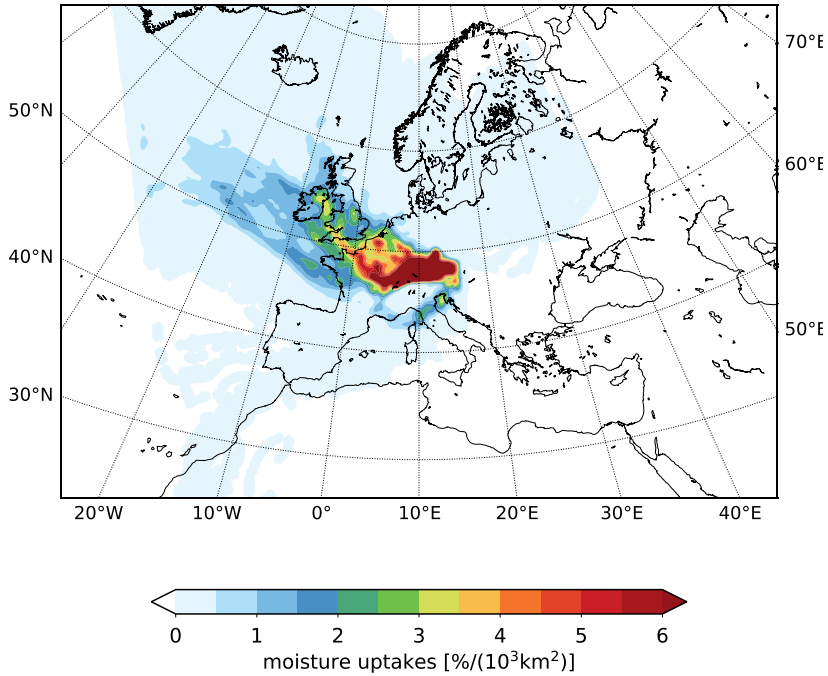


Fig.: Monthly sum of total precipitation in EOBS data (v19.06e, ensemble mean).

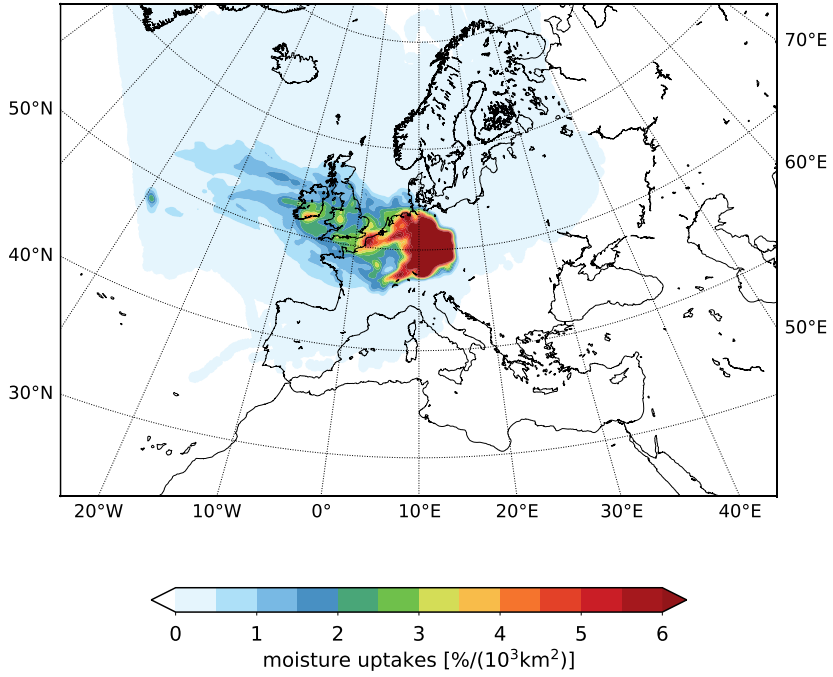
What are the evaporative moisture source regions?

Average moisture uptake from 10.08.2002 00UTC to 13.08.2002 23UTC

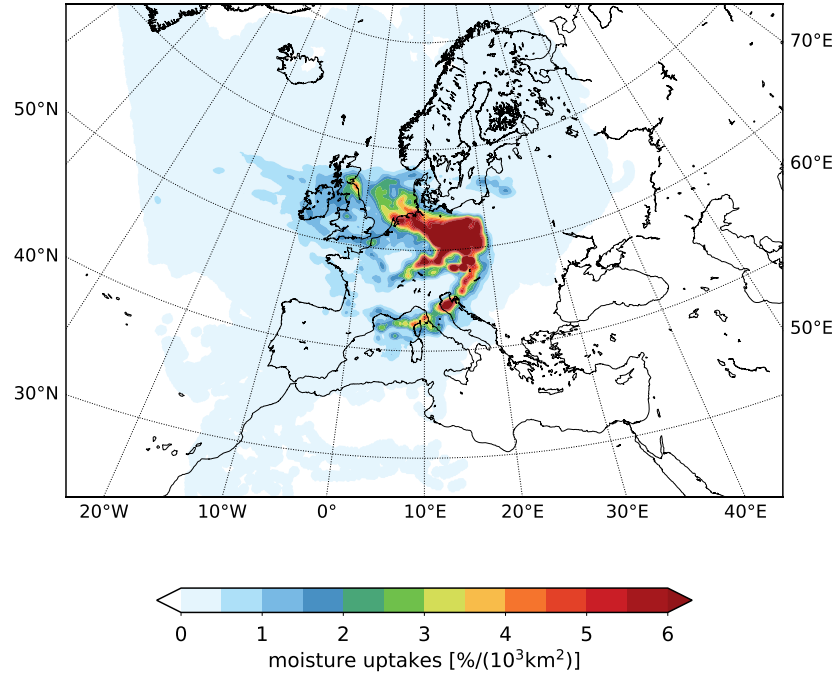
Danube



Elbe



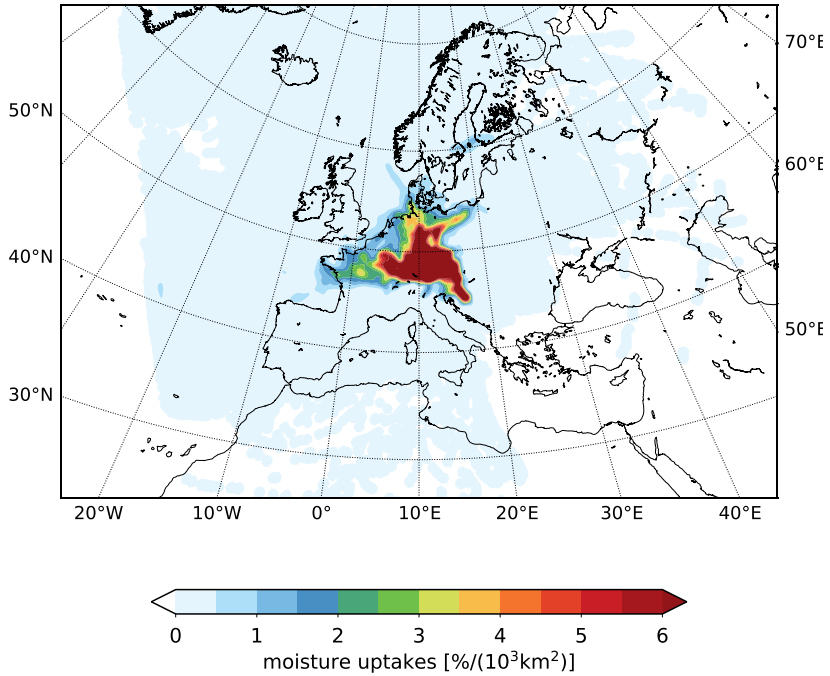
Odra



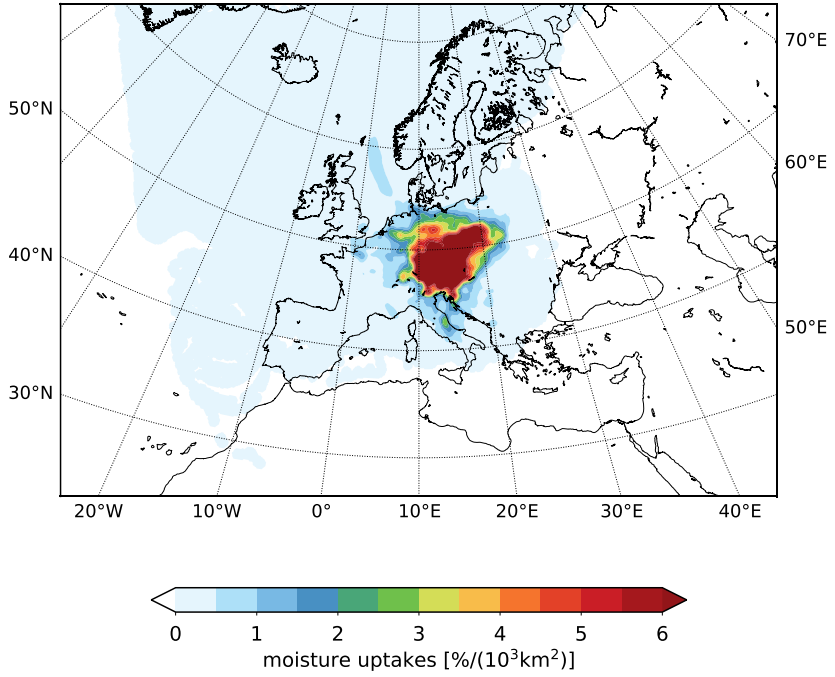
What are the evaporative moisture source regions?

Average moisture uptake in the **Danube** catchment…

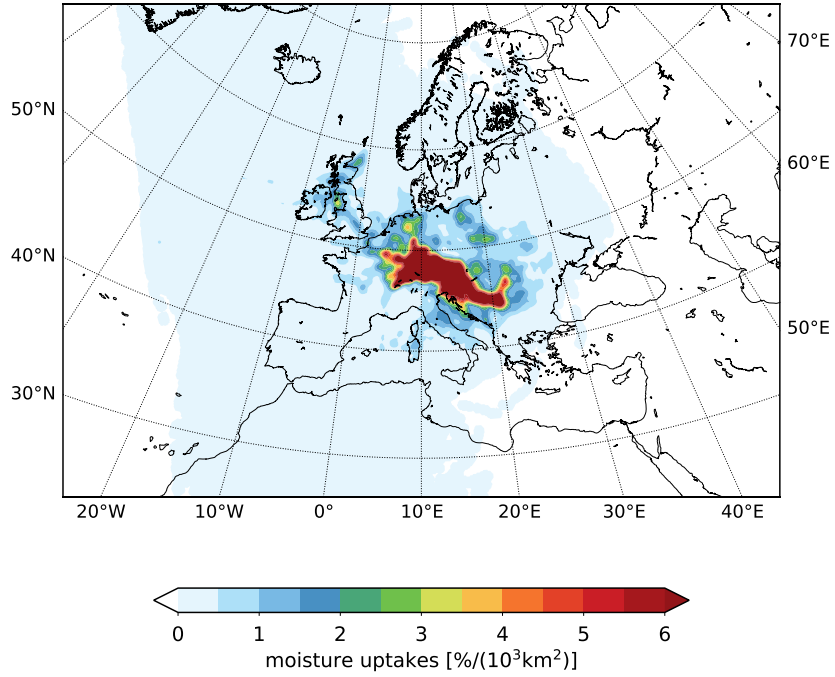
1910



1954



2005



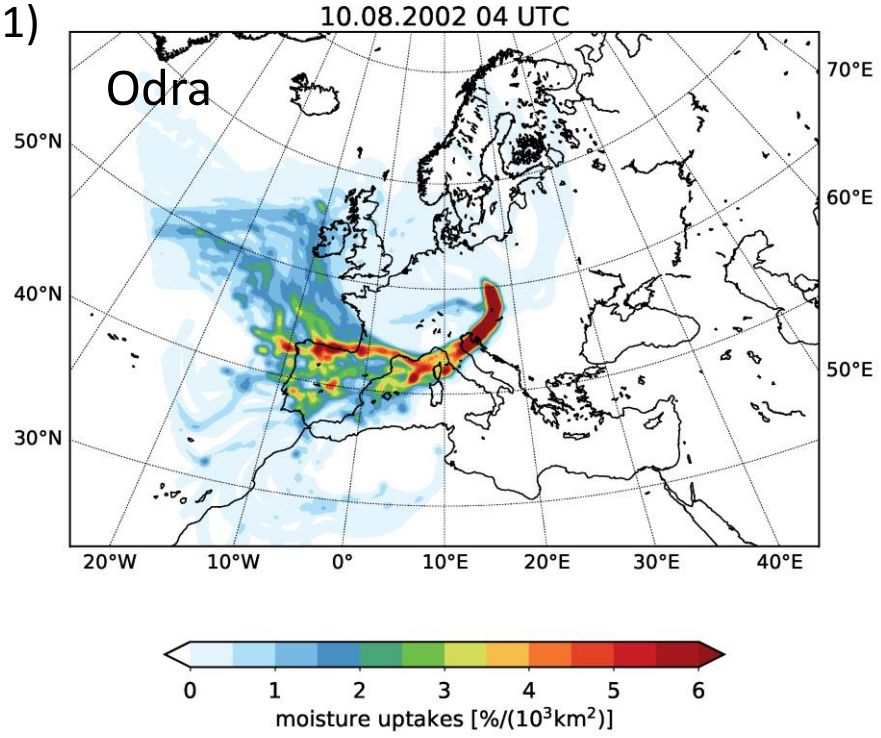
What are the evaporative moisture source regions?

1) The Mediterranean Sea contributed to rainfall in the affected river catchments often at the event start.

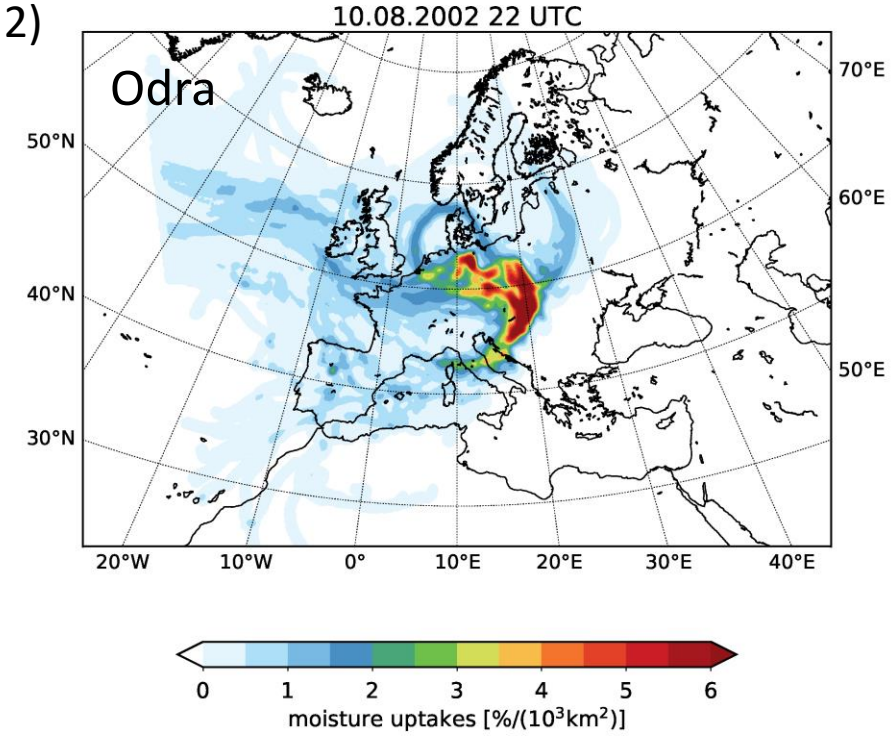
2) Throughout the events, moisture uptake over the European continent dominates pointing towards an important role of the soil-moisture precipitation feedback.

In addition, other oceanic sources such as the North Atlantic, the North Sea, and the Baltic Sea were identified.

1)

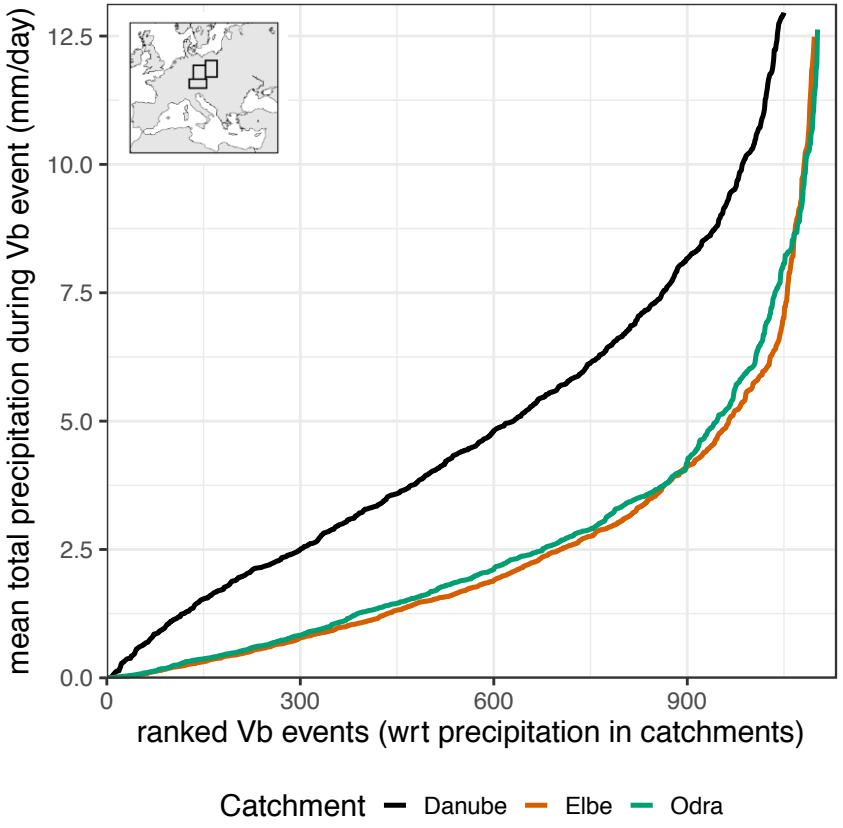


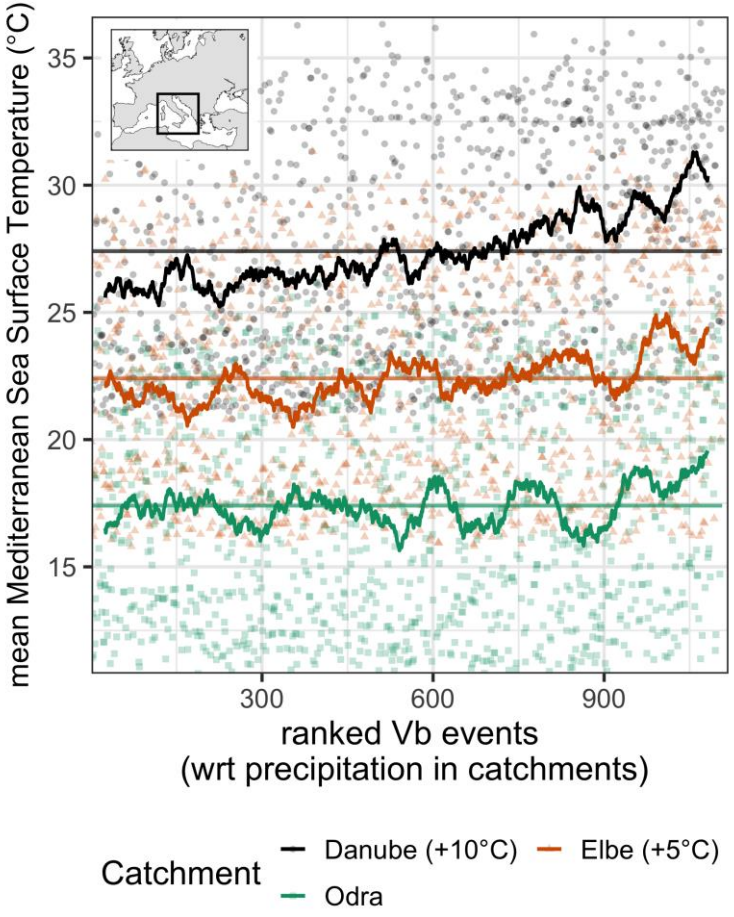
2)



Does high SSTs in the Mediterranean Sea intensify Vb-events?

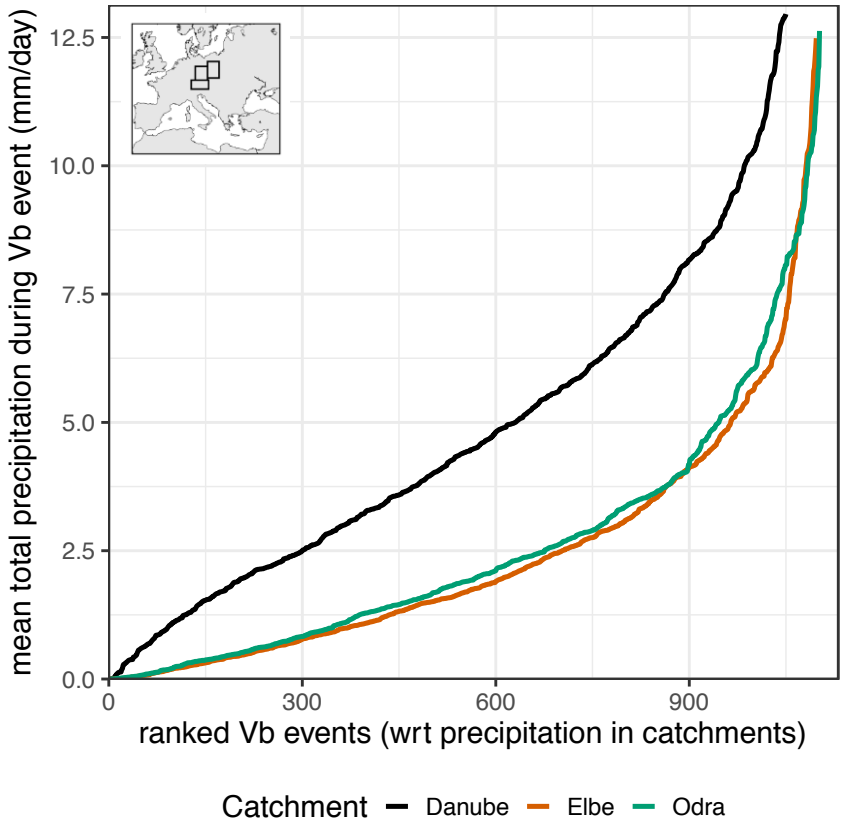
Vb-events with highest ranked precipitation in the river catchments coincide with higher sea surface temperatures in the Mediterranean Sea (Fig, black square).

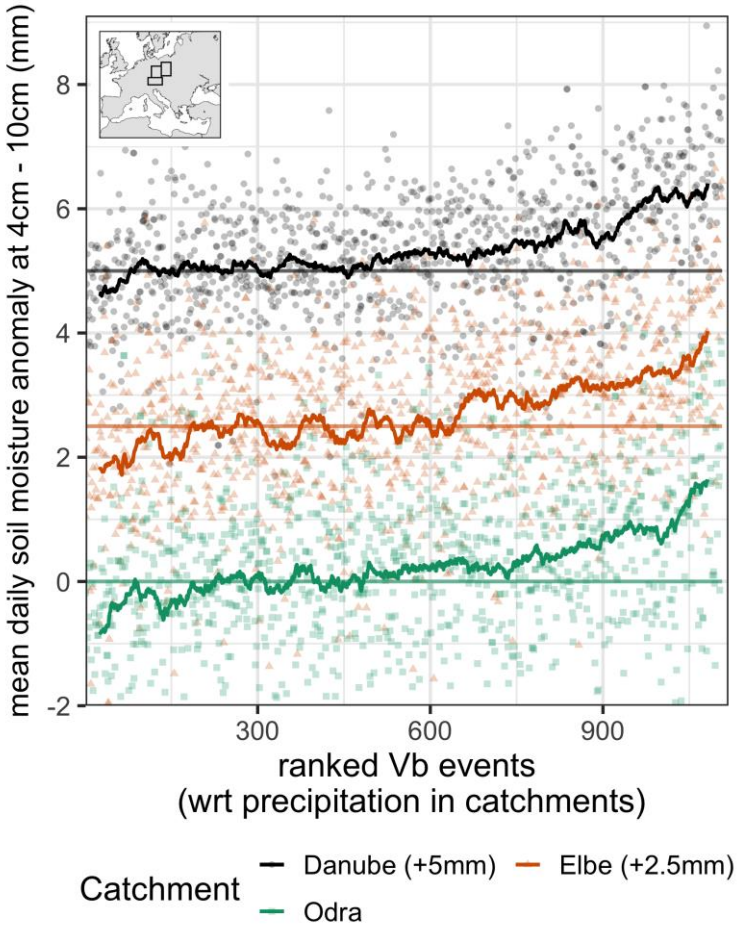




Does soil-precipitation feedback intensify Vb-cyclones?

Vb-events with highest ranked precipitation in the river catchments (black rectangles on map) show positive soil moisture anomalies which points towards the relevance of soil-precipitation feedback.





Conclusions

The **most severe and widespread summer floods** in Central Europe during 1901 – 2010 were associated with **Vb-cyclones**.

Several processes intensify Vb-events during summer and favor a consecutive occurrence. Further research is needed on **positive feedback mechanisms** (Hofstätter and Blöschl 2019).

The **Mediterranean Sea** contributed to rainfall in the affected river catchments often at the event start and **higher SSTs** coincide with **heavy precipitation** Vb events. Interestingly, other important moisture uptake regions were the **North Atlantic**, the **North Sea**, and the **Baltic Sea**.

The **main uptake region** was the **European continent** pointing towards an important role of the **soil-moisture precipitation feedback**. This is supported by the fact that Vb-cyclones with highest precipitation impact correlate with **wet soil conditions** in the river catchments.

Overall, the large variety of the identified sources highlights the complex dynamical interplay of different airmasses leading to convergence of moisture during particularly severe flood producing heavy precipitation events.