From multiscale climate extremes to impact assessment: scientific insights and climate services

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ClimXtreme

Overarching goal: understand extreme weather processes, frequency, intensity and impacts in Europe (heatwaves, droughts, heavy precipitation and windstorms).

- Improve accessibility of climate knowledge: stakeholder engagement.
- Support climate adaptation and decision-making: **post-event analysis**.

RegIKlim/NUKLEUS

Overarching goal: Develop decision-relevant climate knowledge and adaptation solutions for municipalities and regions in Germany.

- NUKLEUS: Generate high-resolution regional/local climate information.
- Provide accessible climate data and services for municipalities, planners and practitioners: **Climate Impact Hub** platform.

Post-Event Assessment Groups

Addresses the demand from media, stakeholders and BMFTR for rapid post-event information: rapid scientific assessments of extreme events.

- Combines quick analysis (**Freva plugin workflow**) with advanced ClimXtreme methodologies.
- Comprehensive reports within 4-6 weeks, available in the website.

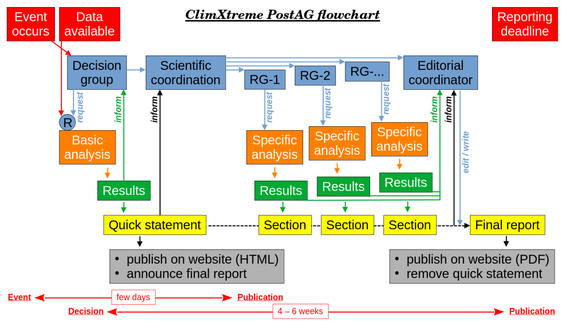

Figure 1: PostAG flowchart (left to right) from basic workflow to final report.

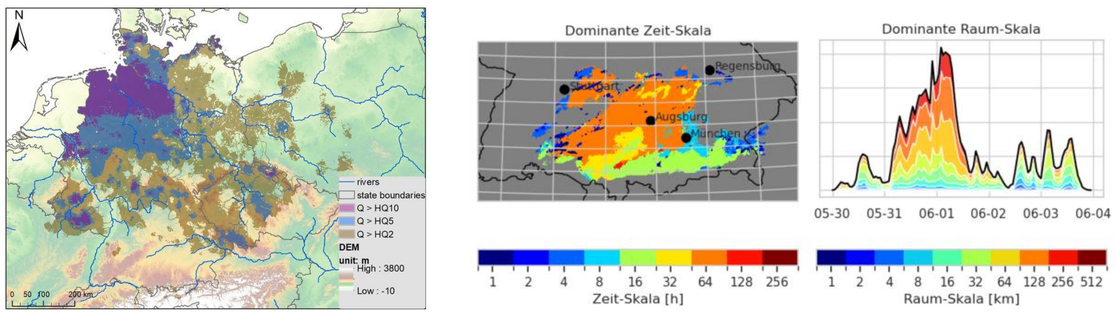

Figure 2: Plots of 2 PostAG reports. (left) Winter flood 2023/24, spatial extent and return periods (HQ2–HQ10. colored) from mHM simulations (1.7x1.7km) driven by E-OBS data. (center & right) Dominant spatial and temporal scales of the May-June 2024 heavy rainfall event from hourly RADOLAN-RW data.

Workflow Strategy (transfer to DWD):

- Jupyter notebooks combining Freva accessible near-realtime data (Era5, Hyras, Radolan…) and analysis tools (plugins).
- One workflow per hazard type (wind, precipitation, heat).
- Event assessments within ~1 hour of data availability.

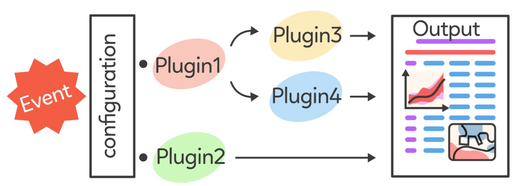

Figure 3: schema of a workflow with a configurable setup, from the event trigger till the creation of a quick report.

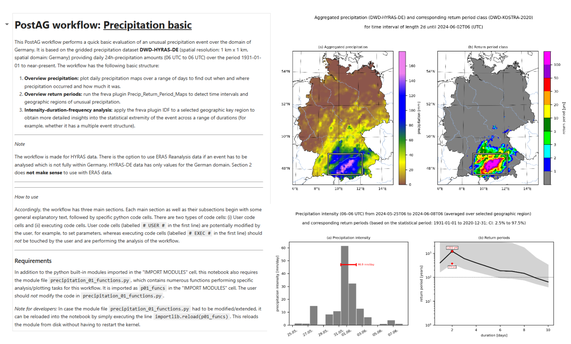

Figure 4: Precipitation workflow used for the May-June 2024 heavy rainfall event (based on 1x1 km Hyras-DE). (left) user friendly design. (right) outputs of 2 plugins; (top) spatial precipitation return periods based on KOSTRA dataset; (bottom) localised return periods and IDF (GEV) extreme-value analysis.

Climate Impact Hub

Nationwide platform for climate adaptation information and services.

- Provides climate and geospatial data at the district level.
- Offers analysis tools, data downloads and climate adaptation guidance.
- Supports practitioners and public authorities with decision-relevant information.

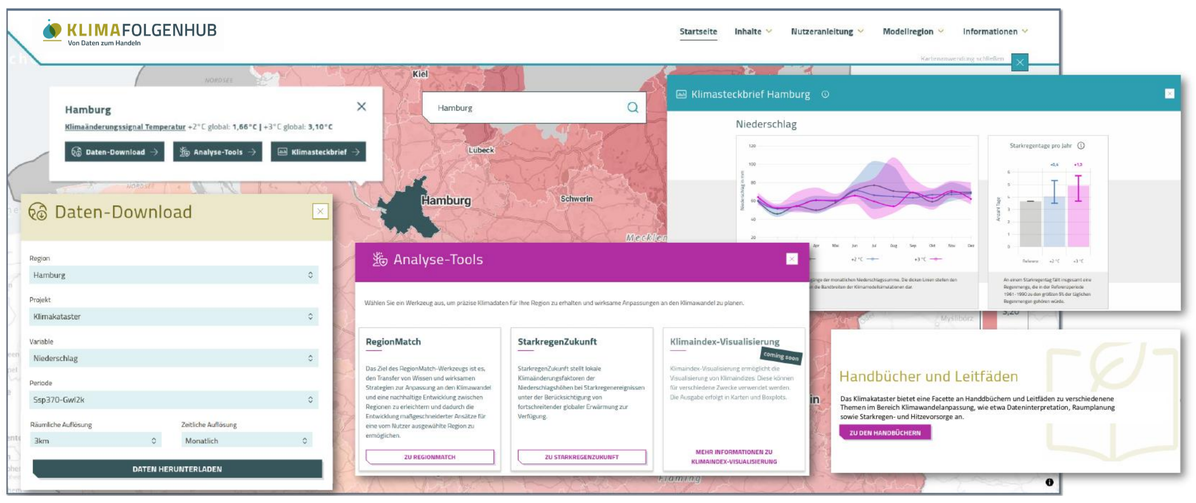

Figure 5: Overview of the platform: data and actions are provided for each of the Kreise (districts), including a summary, data download interface, analysis tools (based on **Freva plugins**), climate profile and additional help.

Under the hood:

- **Server**: operated by DKRZ, Freva as data and analysis framework.
- **Data**: high res climate models (e.g. NUKLEUS 3km ensemble), climate indices, observational, geospatial and socio-demographic data.
- **Analysis tools**: plugins prepared by NUKLEUS / sister projects.

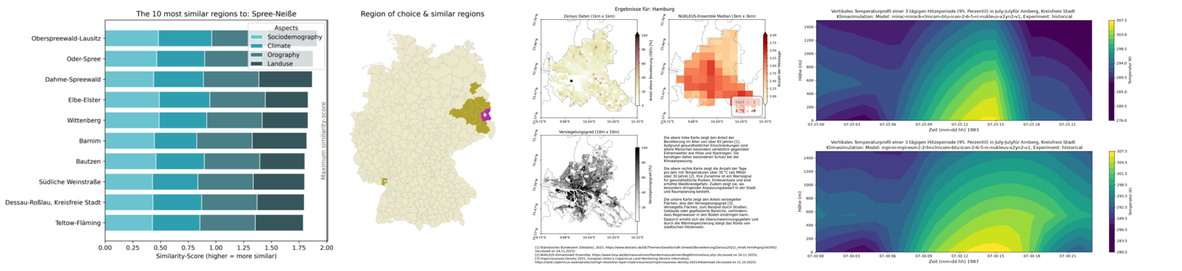

Figure 6: (left to right) RegionMatch (Spree-Neiße) identifies similar German districts using climate, land use, orography and socio-demographic indicators to support transfer of adaptation strategies. KliSoViewer (Hamburg) combines NUKLEUS climate projections (3 km) with census (1 km) and Copernicus land-use (10 m) data to identify climate risks and adaptation needs. Heat2UrbanImpact (Amberg) compares representative extreme heat events across NUKLEUS climate models using ENVI-met to assess urban heat impacts.

Freva & DKRZ Infrastructure

Freva (Free Evaluation System) Features: Datasets + Plugins + Results

- **Via**: web, command line, python module → accessible
- **Datasets**: standardized (>12 million files, multiple formats) → useful
- **Plugins**: any language (>40 plugins available, ~50 in dev/archived) → flexible
- **Results**: stored & shared (>230,000 runs) → reproducible
- >200 unique users from >50 institutions

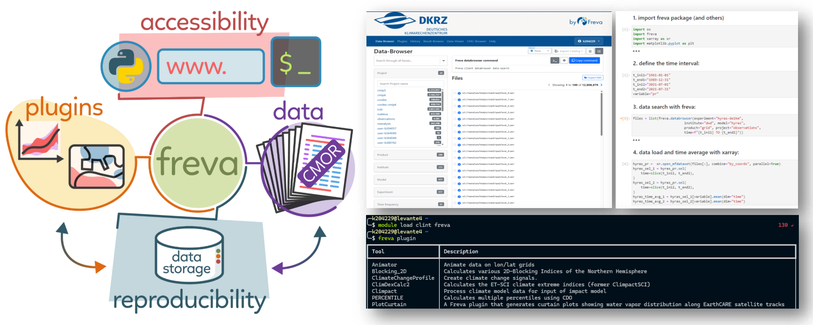

Figure 7: schema of the Freva framework (left), and available access modes to it (right).

DKRZ infrastructure in a few lines:

- **Compute capacity**: 2,982 CPU nodes, 60 GPU nodes (240 A100 GPUs), ~390k CPU cores.
- **Storage**: 130 PB Lustre, ~170 PB archive, S3 object storage.
- **Data Pool**: CMIP3/5/6, CORDEX, ERA5, observations, boundary conditions and shared project datasets. (regular updates in crucial data).
- **Services**: ESGF, Freva, GitLab, Globus, JupyterHub, S3 object storage, DOI publishing and long-term data curation.

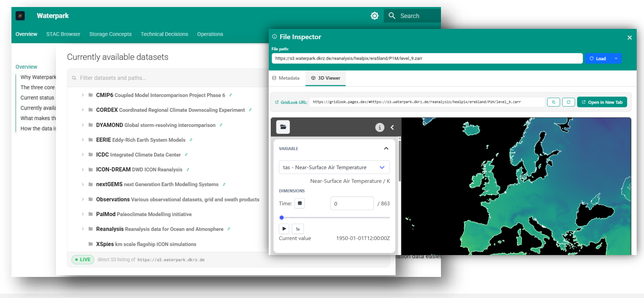

Figure 8: Waterpark, an initiative to openly (s3/zarr) share data in same grid (HealPix pyramids) for a seamless intercomparison.

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