Capture and retain heavy rainfalls in Jordan (CapTain Rain)

Progress report 2023

(January 2023 – December 2023)

Presented by the CapTain Rain project team

Project coordination and contact

Dr. habil Katja Brinkmann (project lead)
Institut für sozial-ökologische Forschung (ISOE)
Hamburger Allee 45
60486 Frankfurt am Main
brinkmann@isoe.de

Prof. Dr. Dörte Ziegler
Hochschule Koblenz (HK)
Konrad-Zuse-Str.1
56075 Koblenz
ziegler@hs-koblenz.de

Number and type of project partners (updated list)

Partner from Germany (Abbreviation)	Type
Institute for Social-Ecological Research (ISOE)	Research Institute
Koblenz University of Applied Sciences (KU)	University
Potsdam Institute for Climate Impact Research (PIK)	Research Institute
HAMBURG WASSER (HW)	Company
KISTERS AG (KIS)	Company
Institute for Technical and Scientific Hydrology GmbH (ITWH)	Company
Partner from Jordan (Abbreviation)	
Ministry of Environment of Jordan (MoE)	Ministry
Ministry of Water and Irrigation of Jordan (MWI)	Ministry
Jordan Meterological Department (JMD)	Research Center
Greater Amman Municipality (GAM)	Administration
Royal Jordanian Geographic Center (RJGC)	Research Center
National Agricultural Research Center (NARC)	Research Center
Petra Development and Tourism Region Authority (PDTRA)	Administration

Table of content

Zusammenfassung

Der Nahe Osten ist in besonderem Maße vom Klimawandel und extremen Klimaereignissen wie Dürren und starken Regenfällen betroffen. In Jordanien haben die wiederholten Starkregenereignisse der letzten Jahre zu Sturzfluten mit enormen Schäden geführt. Zugleich ist Jordanien eines der wasserärmsten Länder der Welt und verfügt nur über wenige erneuerbare Wasserressourcen. Die Minimierung solcher Schäden, aber auch die Maximierung des Nutzens von Starkregenereignissen durch verbesserte Wasserrückhaltung in einem der wasserärmsten Länder der Welt, ist das Forschungsthema von CapTain Rain ("Capture and retain heavy rainfalls in Jordan“). Dazu werden die treibenden Faktoren von Sturzfluten in jordanischen Wadi-systemen analysiert und die komplexen Wechselwirkungen zwischen Klima- und Landnutzungsänderungen und wasserbaulichen Maßnahmen untersucht. Auf der Grundlage von Vulnerabilitätsanalysen und technischen Lösungen für die Wassersammlung und -ableitung bei Starkregenereignissen werden Maßnahmen zum Schutz der Bevölkerung identifiziert. Klimadienstleistungen (z.B. Sturzflutgefahrenkarten, Frühwarnsysteme, Empfehlungen zur Vorbeugung von Starkregenereignissen) werden in enger Zusammenarbeit mit jordanischen Akteuren und Praxispartnern unter Berücksichtigung wissenschaftlicher und lokaler praktischer Erkenntnisse entwickelt. Das Untersuchungsgebiet umfasst die Hauptstadt Amman mit ihren 4,3 Millionen Einwohnern in der Metropolregion und die eher ländlich geprägte Wadi Musa Region um das UNESCO-Weltkulturerbe Petra. Beide Regionen waren in der Vergangenheit stark von Sturzflutereignissen betroffen.

Summary

The Middle East is particularly affected by climate change and extreme climatic events such as droughts and heavy rainfall. In Jordan, repeated heavy rainfall events in recent years have led to flash floods with enormous damage. At the same time, Jordan is one of the most water-scarce countries in the world and has few renewable water resources. Minimising such damage while maximising the benefits of heavy rainfall through improved water retention is the research topic of CapTain Rain ("Capture and retain heavy rainfalls in Jordan (webpage: www.captain-rain.de)". Within the transdisciplinary research project CapTain Rain, the German and Jordanian project partners aim to help improve current methods and tools for flash flood prediction and prevention. For this purpose, the driving factors of flash floods in Jordan's wadi systems will be analysed and the complex interactions between climate and land use changes and hydraulic engineering measures will be unravelled. Based on vulnerability analyses and engineering solutions for water collection and drainage during heavy rainfall events, measures to protect the population will be identified. Climate services (e.g., flash flood risk maps, early warning systems, recommendations for heavy rainfall risk prevention) will be developed in close collaboration with Jordanian stakeholders and practice partners, considering scientific as well as local practical knowledge. The study areas include the capital Amman with its 4.3 million inhabitants in the metropolitan region and the more rural region Wadi Musa around the UNESCO World Heritage Site Petra. Both regions have been heavily affected by flash flood events in the past.

Topics and objectives of the project

Background

The Middle East is particularly affected by climate change and extreme weather events. Over the past 50 years, heavy rainfall events in Jordan have caused many flash floods that lead to significant property damage and fatalities. At the same time, Jordan is one of the most water-scarce countries in the world and has few renewable water resources. Maximizing the benefits of heavy rainfall events in terms of water harvesting and minimizing flash flood damages is therefore one of the most important tasks when it comes to climate change adaptation in Jordan.

One prerequisite for minimizing disaster losses is the ability to accurately predict disaster events so that precautionary measures can be taken. Such “climate services” for risk prevention are a high political priority in Jordan, but have not yet been sufficiently put into practice. Despite recent scientific findings, there is a lack of basic hydrological and meteorological knowledge which is needed to better predict the occurrence and intensity of flash floods in Jordan’s wadi systems. A successful development and implementation of climate services also requires that it is done in cooperation with future users and decision makers. Here, transdisciplinary research methods enable a holistic analysis of flash flood hazards and hazard prevention and facilitate the transfer of scientific knowledge into practical measures for climate change adaptation.

Objectives

CapTain Rain aims to help improve current methods and tools for flash flood prediction and prevention in Jordan. For this purpose, the driving factors of flash floods in Jordan’s wadi systems are analysed and the complex interactions between climate and land use changes and hydraulic engineering measures are deciphered. Based on vulnerability analyses and engineering solutions for water collection and drainage during heavy rainfall events, measures to protect the population are identified.

Climate services (e.g. flash flood risk maps, early warning systems, recommendations for heavy rainfall risk prevention) are developed in close collaboration with Jordanian stakeholders and practice partners, considering scientific as well as local practical knowledge. The transdisciplinary research methods of CapTain Rain enable a holistic analysis of flash flood hazards together with hazard prevention and facilitate the transfer of scientific knowledge into practical measures for climate change adaptation.

For this, CapTain Rain will:

(1) analyse the social-ecological drivers of flash floods in Jordan's wadi systems and entangle the complex interactions between climate and land use change to enable a better simulation and prognosis of flash flood events;

(2) assess the social-ecological risk of flash floods using an integrated vulnerability analysis, taking into account the spatial exposure of flash floods, sensitivity and adaptive capacity;

(3) develop climate services for flood-related decision making based on stakeholder dialogues and participatory approaches;

(4) and identify promising measures to improve the adaptive capacity of local communities, including methods and technologies to capture and retain water from heavy rainfall, but also to prevent damages.

The study areas include the capital Amman with its 4.3 million inhabitants in the metropolitan region and the more rural region around Wadi Musa, including the UNESCO World Heritage Site Petra (Figure 1). Both regions have been heavily affected by flash flood events in the past.

In the past ten years, Amman has experienced a total of six flash floods (Nov 14, Nov 15, Jan 18, Apr 18, Oct 18, and Feb 19). The November 2014 flood was particularly severe, killing three people in Amman, as was the November 2015 flood, which killed four people and caused extensive property damage. Overall, the risk of flash flood events in Amman has increased dramatically due to rapid urbanization in recent decades.

In Petra, in particular, there was a very severe flash flood in 1963, when large parts of the UNESCO World Heritage Site were flooded and about 20 tourists died. In the 1991, 1995, and 1996 flash floods, several tourists had to be evacuated (Al-Weshah/El-Khoury 1999). The most recent severe flash flood in Petra occurred in November 2018 with a total of 12 fatalities, according to media reports.

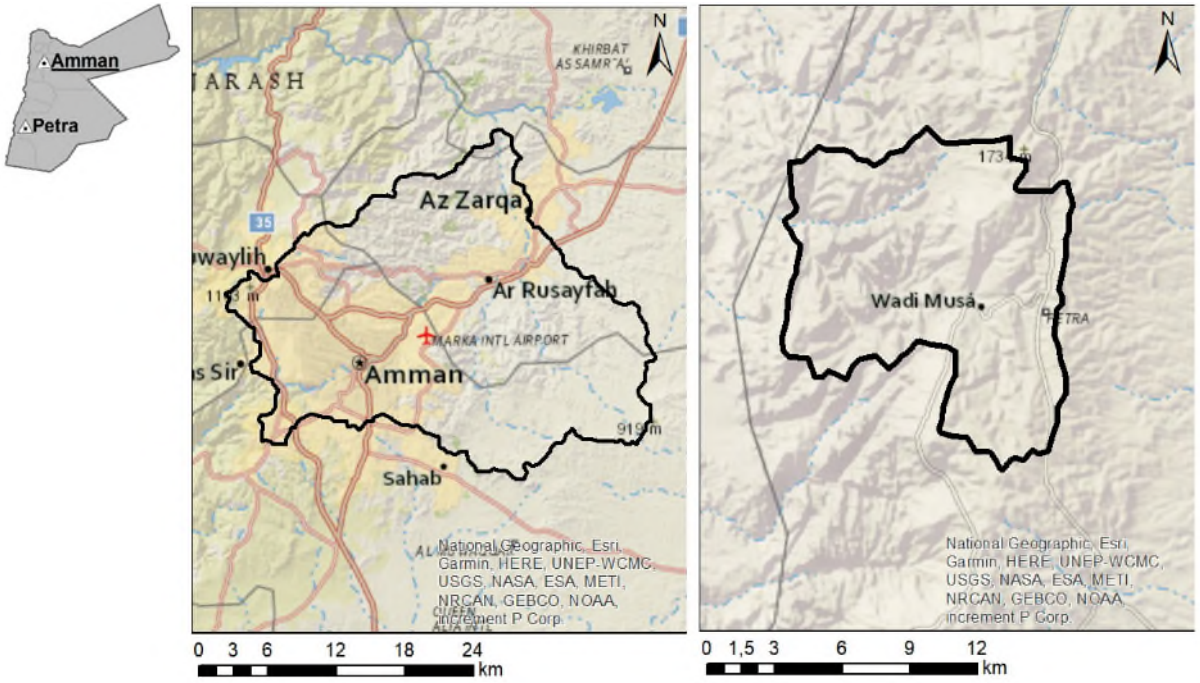

Figure 1. *Overview of the selected study areas: The capital Amman as urban region (left) and the more rural region of Wadi Musa (right), Jordan (satellite image scene in the background: Sentinel-2B, April 2019).*

Project structure

An integrated vulnerability analysis of flash floods is carried out in close collaboration with relevant stakeholders, which includes the analysis of the socio-ecological causes of flash floods and the identification, mapping and assessment of flash flood risks (exposure and sensitivity). In addition, risk perceptions are investigated from the perspective of the local population and strategies for adaptation to heavy rainfall events are developed. Model-based scenarios are used to develop and evaluate measures to improve risk preparedness, including technologies to divert and use water from heavy rainfall events. Climate services for the prevention of heavy rainfall risks are prepared and made available in a participatory manner.

Altogether, six work-packages (WP) with researchers from Germany and Jordan contribute to the analysis of flash floods including the integrated vulnerability analysis and provide a revision of the current methods for flash flood prediction and prevention. Each WP is subdivided in two sub-work packages (SWP), expect of WP 3, which comprises three sub-work packages (Figure 2).

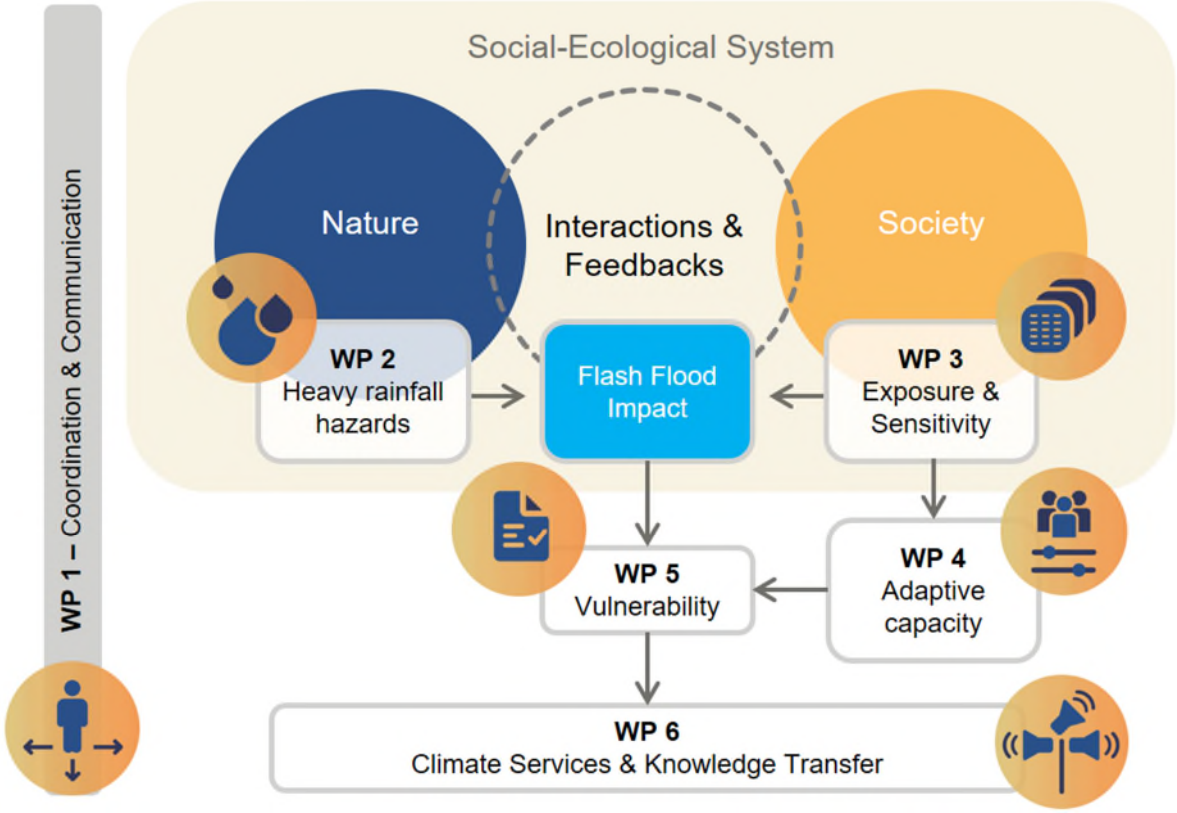

Figure 2. *Conceptional framework of the integrated vulnerability analysis of flash floods and associated WPs.*

All WPs are closely linked to each other in a network that allows synergistic interactions. WP 1 “Coordination & Communication” encompasses the central project management including the scientific and technical coordination as well as the stakeholder integration and communication. WP 2 “Heavy rainfall hazard” focusses on an improved understanding of flash flood hazards in wadi-systems and investigates how heavy rainfall events have changed in the past and may continue to change in the future due to climate change effects. The spatial and temporal impacts of flash floods on people, infrastructure, and ecosystem services along an urban-rural gradient are analysed in WP 3 “Exposure & Sensitivity”. WP 4 “Adaptive Capacity” investigates the local knowledge of severe flash flooding and adaptation strategies, as well as potentials to improve methods and technologies to capture and retain heavy rainfall events through assessment of different water adaptation technologies. The results of WP 2-4 are synthesized to conduct an integrated vulnerability assessment and a scenario analysis of different adaptation strategies in WP 5 “Vulnerability”. WP 6 “Climate Services & Knowledge Transfer” focusses on the provision of climate services for climate and flood related decision-making and communication of flash flood risks and impacts.

Status quo of the project and achievements in comparison to the milestones set in the proposal

The interdisciplinary cooperation between the different WPs is made possible in CapTain Rain through an overarching research design (Fig. 2). At the same time, a transdisciplinary approach is taken to ensure early stakeholder integration and the alignment of the project with the on-ground problem and need situation. The work of the individual WPs is closely interlinked. The tracking and follow-up of coordination and agreements is carried out along the WP/topic responsibilities.

In the year 2023, the different WPs continued their research activities with stakeholder workshops, data analysis and processing, refinement of models and simulations. Numerous internal project events were carried out (online project meetings, meetings of WP-teams, etc.). In total, two large stakeholder workshops in Amman, one stakeholder workshop in Wadi Musa, three major project meetings (two online and one in presence) and two meetings of the steering committee (online) took place during the reporting period. In addition, numerous bilateral meetings have taken place with Jordanian partners, online and in presence during field trips to Amman and Wadi Musa.

The scientific-technical milestone M3 was successfully reached in late summer 2023 (Table 1). This milestone included the implementation of the hydrological and hydraulic models and the simulation of the current situation and flash flood risk mapping (WP 3) as base data for the vulnerability assessment in WP 5. Furthermore the second stakeholder workshop (SW 2) and participatory validation of model results in addition to risk mapping has been successfully conducted and promising adaptation strategies have been identified with stakeholders (WP 4). The design and specification of the early warning system (EWS) demonstrator has been completed (WP 6).

Table 1. *Overview of milestone status:*

	Description of Milestone	**Date of completion**	**Status**
M1	Planning-organizational milestone; Inventory completed	11/2021	fulfilled
M2	Scientific-technical milestone; Preliminary investigations carried out	12/2022	fulfilled
M3	Scientific-technical milestone; Models implemented and simulations completed	07/2023	fulfilled
M4	Assessment-related milestone; Integrated scenario and vulnerability analysis conducted	11/2023	partly fulfilled
M5	Utilization-related milestone; Dissemination of climate services successfully carried out	07/2024	pending

The assessment-related milestone M4 was partly fulfilled until the end of 2023. For this, the vulnerability and scenario analysis started (WP 5). For the integrative assessment vulnerability indicators were identified and calculated and the preliminary assessment was carried out together with the relevant stakeholders in the framework of the third stakeholder workshop (SW 3). Adaptation strategies for implementation were identified together with the stakeholders on the basis of the results and the

corresponding risk mapping. Training programs for stakeholders were prepared and already partly implemented (WP 6).

Highlights and difficulties

The year 2023 began with a successful **second stakeholder workshop**, which took place on 30.01.2023 at the Geneva Hotel in Amman with 40 participants (Fig. 3). In addition to the presentation and discussion of the latest research results, a group work was conducted to discuss planning goals for flash flood damage reduction measures in Amman and the early warning chain in Jordan. Before and after the workshop numerous meetings with the Jordanian project partners, on-site visits, expert interviews and an excursion to Wadi Musa/Petra took place. New data sets from GAM about Amman's infrastructure and rainfall and temperature data series from the MWI were acquired which helped to improve CapTain Rain model results.

***Figure 3**. Impressions of the group work on planning goals during the second stakeholder workshop in Amman.*

In June 2023, the Captain Rain project participated in the **7th International Symposium on Flash Floods in Wadi Systems** (ISFF7). The event was held in Tlemcen, Algeria from June 5.-7. The symposium was an important opportunity for exchange and collaboration between scientists and practitioners mainly from the MENA-region. The 7th edition of the symposium focused on flash floods and sediment management in wadi systems in the context of climate change. Three topics from different WPs of the CapTain Rain consortium were presented. Christina Maus from Koblenz University of Applies Sciences gave a presentation on "The multi-model approach for flash flood modelling in data- and water-scarce regions like Jordan". Dr. Peter Hoffmann from the Potsdam Institute for Climate Impact Research (PIK) presented a poster on the "Causal linkage between extreme rainfall in Jordan and large-scale circulation patterns". Another poster was presented by Ahmad Awad from the Institute of Social-Ecological Research (ISOE) on "How have land cover changes and urbanization contributed to the flash

flood risk in the city of Amman? An analysis of past and future trends". During the symposium the CapTain Rain team had many fruitful discussions with experts and established and strengthened contacts for collaboration.

On the 19th and 20th of September 2023, the German project partners met at PIK to present and discuss the latest results of the different WPs as well as the next steps of the integrated vulnerability assessment and scenario modelling. Members of the CapTain Rain team also participated in the **WaX-Seminar**, which took place on the 20th and 21st of September in Potsdam as well. 'WaX – Hydrological extreme events' is another funding measure within the BMBF strategy "Research for Sustainability (FONA)". As WaX aims to investigate possible adaptation measures and improved management strategies to diminish the consequences of droughts, heavy rainfall and floods, it was very interesting to get an insight into the research activities of the different projects, to discuss possible approaches and synergies among projects.

Due to the Middle East conflict, which started in October 2023, the travel plans of the CapTain Rain team for the **third stakeholder workshop** have been postponed slightly. For security reasons, the German team only traveled to Jordan with a limited number of team members in December. Despite the political uncertainties and the Middle East crisis, the workshop was held successfully, albeit with a limited number of participants. The workshop took place at the Al-Hussein Cultural Center **in Amman** on Monday, December 11, 2023 (Fig. 4). Around 30 project partners and Jordanian experts participated in this event. In addition to the presentation and discussion of the latest research results, scenarios for integrated modeling and vulnerability assessment were selected during group work sessions. To evaluate the scenarios, vulnerability indicators were discussed and ranked according to their importance. Further meetings with the Jordanian project partners and field visits took place before and after the workshop. On December 13, 2023, another **stakeholder workshop** was held **in Wadi Musa** at the PDTRA office. The main objective was to jointly select planning goals for the Wadi Musa region and discuss measures that have the potential to decrease flash flood damages.

Figure 4. *Group work during the third stakeholder workshop in Amman (left) and in Wadi Musa (right).*

The CapTain Rain project co-starred in the regional video for the MENA region produced by the funding initiative "**CLIENT II** - International Partnerships for Sustainable Innovations" and contributed to a Client II SDG story (https://bmbf-client.de/neuigkeiten/sdg-erfolgsstory-captain-rain-1).

So far, the team of the CapTain Rain project has successfully finalized **17 publications and conference contributions** and also contributed to capacity development at the university level by supervising two Bachelor and one Master thesis.

Status quo of the workpackages

WP 1 „Coordination & Communication“

WP 1 "Coordination & Communication" encompasses the central project management including the scientific-technical coordination, the internal and external communication as well as the transdisciplinary integration. The sub-work package (SWP) 1.1 “**Stakeholder dialogue and transdisciplinary integration”** serves as an interface for external communication between science and society. As such, it includes a stakeholder analysis at the beginning of the project complemented by expert interviews in Jordan. The stakeholder dialogue aims to anchor and consider opinions, relevant practical knowledge and experience, and needs of societal (practical) actors in the project. The communication of knowledge and the active involvement in the findings and techniques for the prediction and prevention of flash flood risks takes place via annually coordinated stakeholder workshops. This will lay the foundation for the transfer of knowledge into practice in WP 6 and enables the early dissemination of the project results. The sub-work package 1.2 “**Scientific and internal project coordination”** coordinates the project activities of the consortium and is responsible for the scientific and internal communication in order to coordinate the different research activities during the project duration in a way that ensures the development of methods and tools (e.g. integrated vulnerability and scenario analysis). In addition to the project website, tools for web-based research data management are delivered to facilitate inter- and transdisciplinary collaboration through a common and transparent data basis. To ensure the involvement of the Jordanian partners and the utilization of the result, a steering committee is established.

Achievements in relation to milestones/work plan and intermediate scientific results

WP 1 coordinated three stakeholder workshops in Jordan, three major project meetings (two online and one in presence) and two meetings of the steering committee (online) during the reporting period. The **second stakeholder workshop** was scheduled for January 2023 ("Validation and scenario development": presentation and discussion of first intermediate results related to modelling and assessment of flash flood risk and measures to prevent flash flood damages). The main objectives of this workshop comprised participatory validation of interim results and subsequent fine-tuning of model results, as well as a joint identification of promising adaptation strategies for scenario development in WP 5. During the workshop the **second formative evaluation** of the work processes and quality control outcomes was conducted. The purpose of the internal project evaluation is “assessing for learning” which means that the project is assessed by the project team (all German and Jordanian partners) in order to learn from it together. The internal project evaluation provides feedback and guidance that should lead to adjustments in the implementation of the project by helping to identify opportunities for improvement and serving as quality control for the project. For a detailed description on the evaluation criteria’s, please refer to the progress report of 2021. The results of the evaluation were compiled with the help of a performance spider to allow an overall evaluation (Fig. 4). Most categories were rated as "good" (4) on average, with the exception of "sustainability", with a lower rating close to 3 (satisfactory). The evaluation of the sustainability is based on the possible or successful implementation by practice partners, but also on potential links for applications and the further use of the results in science after donor funding has been withdrawn. The results were disseminated within the project network and recommendations for improvements in specific field were jointly discussed and decided. To ensure that project results being put into practice within the project period (category “sustainability”), measures have

been taken in the different WPs to improve the usability of CapTain Rain products and better align them to the needs of local stakeholders.

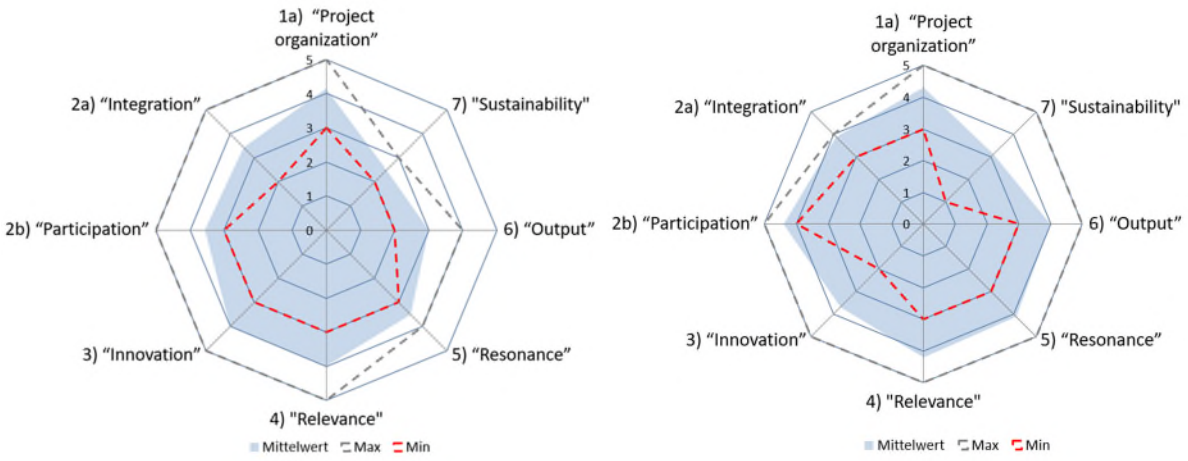

***Figure 4**. Evaluation results for 2023 with German partners (left) and Jordanian partners (right) showing the evaluation of the current state based on own past project experience on a scale of 1 (very poor/not fulfilled) to 5 (excellent/ has been completely fulfilled). For details on the criteria's please refer to the progress report 2021.*

A large **project meeting** was organised and scheduled on the 19th and 20th of September 2023 in Potsdam at the PIK. The project team discussed possible climate (rainfall) land use and land cover change scenarios that will be combined with flash flood protection measures. The results of the joint meeting delivered the basis for further research in the WPs as well as the starting point for the preparation of the third stakeholder workshop.

The organization of the **third stakeholder workshop** was affected by the start of the Middle East conflict in October. Travel plans were postponed and the German team only travelled to Jordan with a limited number of team members in December for security reasons. The workshop took place on Monday, December 11, 2023, at the Al-Hussein Cultural Center **in Amman** (Fig. 4). Around 30 project partners and Jordanian experts took part in this event. Of particular importance was the discussion of the scenarios for integrated modeling and vulnerability assessment, but also the agreement on the completion and transfer of the CapTain Rain products, together with the Jordanian partners. Further meetings with the Jordanian project partners and field visits took place before and after the workshop. In addition to the workshop in Amman, a **further workshop** was held at the PDTRA office **in Wadi Musa**. The main objective was to jointly select planning objectives for the Wadi Musa region and discuss measures that have the potential to reduce flash flood damage.

Reports with documentation were prepared **for the second and third stakeholder workshop**, which were made available to the Jordanian partners and participating stakeholders.

Public relation works in 2023 mainly included the regular upload of news and publications to the webpage (www.captain-rain.de) and the participation in Client II events, which also comprises an interview with the project administrator for the Client II regional video MENA (https://www.youtube.com/watch?v=8tWdIuXdoJI) and a CapTain Rain SDG story contribution (https://bmbf-client.de/neuigkeiten/sdg-erfolgsstory-captain-rain-1).

A layout for **fact sheets** was designed and will be used by the different WPs as a common layout to draft information material on the relevant outcomes and products. In addition, news on ongoing project

activities were lunched at the ISOE webpage (e.g. https://www.isoe.de/en/news/how-to-adapt-to-heavy-rainfall-innovative-solutions-in-jordan/).

Inter- and transdisciplinary cooperation, highlights and difficulties

Based on the stakeholder analysis at the beginning of the project, as well as the implementation of regular stakeholder workshops, this WP provides the basis for stakeholder integration for all WPs and the transfer of knowledge into practice (see also SWP 6.2). The scientific coordination and internal communication ensured the coordination of all WP activities among each other to pave the way for the integrative vulnerability analysis in WP 5.

While the focus in 2022 was still on understanding the Jordanian conditions, problems and preferences as well as the urgent need of data generation, the focus in 2023 changed. Good relationships and working cooperation were established – also thanks to the early second Stakeholder Workshop in Jordan in January 2023. Hence, the focus was on the research work in the different WP, especially in the first half of 2023. With the project meeting in September 2023 the process of integration of results and individual pre-products started. A major driver was the joint work on the vulnerability analysis and assessment in WP 5 which its integration potential as all work strands contribute: The climate scenarios on heavy rainfall events of WP 2, the hydrological and hydraulic models and simulations in WP 3, as well as the work on promising measures that have the potential to decrease flash flood damages in WP 4 were integrated in a model-based scenario analysis, which serves as a decision-support tool in urban planning.

Additionally a strong focus was set by the project coordination on the transfer and utilization of the results. Therefore, the efforts to generate first products and discuss their utilization were intensived and resulted in a first bundle of successful events' contributions (see e.g. the product overview of WP 2 and the successful implementation of the demonstrator as a tool for early warning systems in WP 6, which was successfully tested and used by the Jordanian partners in 2023).

Future prospects/outlook 2024

The work of WP 1 will continue with regular meetings to coordinate the CapTain Rain project. Stakeholder dialogues and communication will continue on a regular basis. In January 2024, the third internal project evaluation will be conducted with all partners. In spring 2024, the organization of the final event of the Captain Rain project is one of the main tasks in WP 1. The event is planned for end of June and will take place in Amman and Wadi Musa. Another task will be the regular maintenance of the project website, which also includes the provision of project results and the cloud-based management of research data beyond the end of the project.

WP 2 „Heavy rainfall hazards"

This WP aims to identify meteorological drivers of heavy rainfall in Jordan in the context of climate change. For this purpose, we analyse long-term local rainfall data provided by the Jordanian partners, global and regional reanalyses, high resolution satellite rainfall estimates as well as weather forecasts and climate scenarios. The research question to answer is, how heavy rainfall events and patterns in Jordan will change in frequency and intensity under different global warming levels. A diagnostic approach to detect critical circulation patterns is one relevant aspect to bring local extreme events in a larger context for reasons of causality. Thus, the WP is divided into two sub WPs focusing in a retrospective/diagnostic part (2.1) and a prognostic part (2.2). The overarching goal is an evaluation of

the climate sensitivity on heavy rainfall events in Jordan. These results are the basis for early warning, climate services and flash flood mitigation actions provided in the other WPs.

Achievements in relation to milestones/work plan and intermediate scientific results

short	long	time	status	comment
WP 2.1:	**Retrospective analysis of heavy rainfall events**	---	---	---
2.1.a:	Data acquisition and processing	Jun21-Aug21	100%	finished
2.1.b:	Climate analysis and monitoring	Sep21-Feb22	100%	finished
2.1.c:	Classification of circulation patterns	Mar22-May22	100%	finished
2.1.d:	Qualitative prediction of heavy rainfall	Jun22-Aug22	100%	finished
2.1.e:	Data integration finished	Sep22-Nov22	100%	finsihed
WP 2.2:	**Modelling of heavy rainfall**	---	---	---
2.2.a:	Predictors for heavy rainfall	Dec22-May23	75%	finished
2.2.b:	Climate sensitivity of heavy rainfall	Jun23-Nov23	75%	ongoing
2.2.c:	Limitation of predictability	Dec23-May24	75%	ongoing

SWP 2.1: Retrospective analysis of heavy rainfall events

2.1.a: Data acquisition and processing

In 2023 we received hourly station data of meterological parameters for selected extreme rainfall events in Amman provided by the Jordan Meteorological Department (JMD). One of these events from 28th February 2019 was selected as the baseline scenario for our integrated scenario analysis in WP 5. For analyzing long-term trends in precipitation we analysed regional reanalysis data (UERRA) from 1961 to 2018. The results highlighted that the mean precipitation in Jordan is decreasing while the yearly maximum of daily precipitation showed increasing trends in the western part of Jordan. Based on this dataset maps were derived showing return levels (2 to 100-yr) of extreme daily precipitation (Fig. 5).

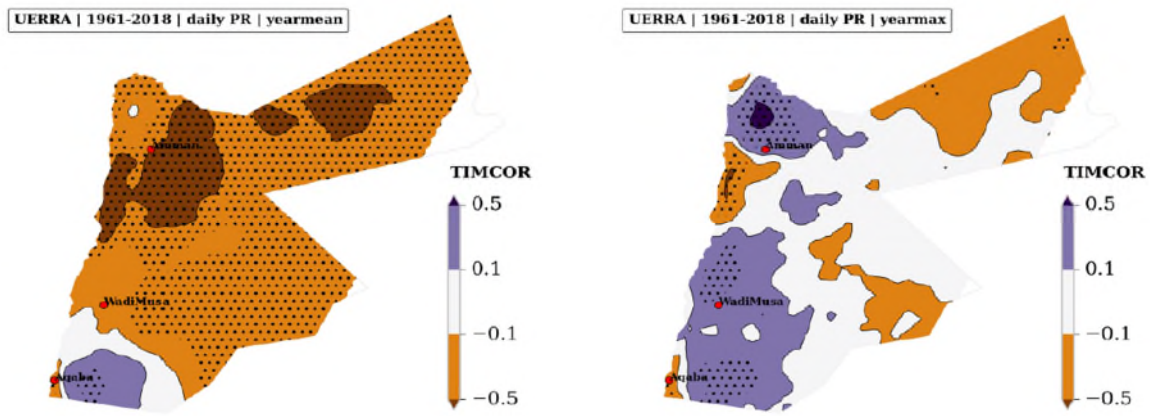

***Figure 5**. Maps showing spatial patterns of the temporal correlation to the mean precipitation (left) and the extreme precipitation (right). A positive correlation is associated with increasing trends.*

2.1.c: Classification of circulation patterns

status: finished (see P3)

2.1.d: Qualitative prediction of heavy rainfall

status: finished (see P4)

2.1.e: Data integration finished

status: finished

WP 2.2: Modelling of heavy rainfall

2.2.a: Predictors for heavy rainfall

status: finished (see P4)

2.2.b: Climate sensitivity of heavy rainfall

In 2023 we continued our analysis of future climate scenarios by using an available ensembles of high-resolution climate model simulations for Europe (including Jordan) with a grid size of 12 km and 3 hours temporal resolution. Previous results on a daily basis have shown, that the number of critical events associated with heavy rainfall in Amman will decrease under future conditions. However, the intensity of such events could increase with rising temperature. Our new results form the basis for our integrated scenario analysis and highlight a future increase in the magnitude of 3-hour rainfall by about 15% for a 100-yr events compared to the historical period. In contrast to that, the longer the event length the lower the climate sensitivity. The results are in agreement with other studies and known physical theories.

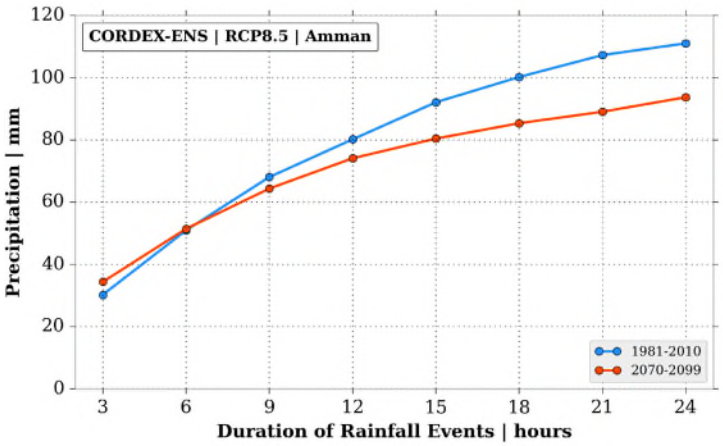

Figure 6. *Comparison of the 100-yr return level of precipitation (3 to 24 hr events) in Amman for historical (blue) and future (red) climate conditions based on a regional climate ensemble. An intensification can be only identified for short-term events (<6 hr) by about 15%. The longer events persist the lower the future return level compared to the historical period.*

2.2.c: Limitation of predictability

The predictability of local extreme precipitation events is limited due to the spatial and temporal scale of the meteorological phenomena. Thus, retrospective analysis of causal linkages between local extremes and large-scale circulation patterns are used to better assess short-term and long-term changes in the weather variability. Within this sub-WP we analyzed climate scenarios in terms of the simulated weather variability in comparison to the real world. We found that models over-estimate westerly wind patterns

and possibly under-estimate (meridional) patterns associated with dry conditions in Western Europe and very wet conditions in the eastern Mediterranean region.

Overview of products delivered by WP 2

P1: Climate Service Portal for Jordan:

The Potsdam Institute for Climate Impacts Research is operating since many years a climate service portal on a country level. In 2023 we integrated Jordan as a new country and as the first country in the Near-East region (https://kfo.pik-potsdam.de//jor/index_en.html?language_id=en). The climate scenario data come from the ISIMIP project (https://www.isimip.org/) and were processed for the target country. Within the climate sector users are able to inform about the future development of relevant climate indicators (e.g. extreme precipitation) under different emission scenarios until 2100 given as maps, charts or tables. This web service is offered in different languages (e.g. arabic) and also enable to integrate project results and digital materials (e.g. fact sheets).

P2: Fact Sheets:

Drafts of two fact sheet were finalized addressing the diagnostic of critical weather patterns (AP2a) and the rainfall scenarios analysis (AP2b) for Jordan.

P3: Objective Classification of Weather-Types for the Eastern Mediterranean area:

By request from the Jordan Meteorological Department (JMD) we developed a software for objectively clustering recurring large-scale circulation patterns for the Eastern Mediterranean area. This approach convert daily atmospheric fields to a sequence of categorical data back to 1981. The retrospective analysis of the attributes enable to identify critical weather-types associated with extreme precipitation in Jordan. In addition, there are connection options for better assessment of atmospheric fields predicted by operational weather forecasts models. Our focal point at JMD was interested in such a time series of weathertype sequences for internal use. See also: https://gitlab.pik-potsdam.de/peterh/jmd

P4: Software: Ensemble Prediction of Weather-Types for the Eastern Mediterranean area:

The application of the objective classification (re-identification) of large-scale recurring weather-types is to reduce complexity of predicted atmospheric fields by operational weather forecast models. One public available forecast member (GFS) has be used to operationally classify predicted atmosphere fields to an existing catalog of weather-types. The monitoring of the resulting labels enable experts to monitor structural changes in the revailing weather-regimes in the Eastern-Mediterranean area with relevance to meteorological phenomena in Jordan. Expert knowledge are integrated in the risk assessment of critical weather-types. The software was compiled to an executable program that can be run without programming skills. The source code and documentation is available in a gitlab repository: https://gitlab.pik-potsdam.de/peterh/gfswt

Inter- and transdisciplinary cooperation, highlights and difficulties

The available regional climate ensembles and precipitation events of WP 2 are used in WP 3 for the risk analysis. All available climatological information is organized in a data management system for further processing. The data products and their processing used in SWP 2.1 flow directly into SWP 6.1 and provide the basis for the development of an early warning system (EWS) in the form of a demonstrator. The analysis of future climate scenarios in SWP 2.2 will be directly used in WP 5 for future scenarios that also consider changes in heavy rainfall events. Collaboration within the CapTain Rain project team

(exchange on data and derived products on availability, quality, processing, integration, accessibility and interpretation of results) was conducted during monthly meetings.

Overview of WP-specific trainings/workshops, publications and conference contributions, supervised Master and/or Bachelor thesis:

Feb 2023	Participation on the 2.Stakeholder Workshop in Amman and Petra
Jun 2023	Participation the International Symposium for Flash Floods in Wadi System im Algeria
Feb 2023	Participation on the 3.Stakeholder Workshop in Amman and Petra
Publications	Three publications have been finalised. See overview list on page 28
Capacity building	Single lectures at FU Berlin, Charité Berlin and EBS Wiesbaden

Future prospects/outlook 2024

Jan-Feb	Finalizing the future extreme rainfall scenario for Jordan Finalizing products for practical application together with JMD
Mar-Apr	Co-Organizing Deutsche Klimatagung 2024 in Potsdam (https://dkt-13.de/)
May-Jun	Preparing the final Stakeholder Workshop in Amman

WP 3 „Exposure & Sensitivity“

WP 3 analyses the spatial and temporal impacts of flash floods on humans, infrastructure, and ecosystem services. Exposure or spatial occurrence encompasses the hazard analysis due to flash floods. Sensitivity determines the potential for damage in areas affected by heavy rainfall. This WP is subdivided in three Sub-WPs. The hazard analysis and the analysis of damage potentials are combined for the preparation of risk maps and assessments. This will lay the foundation for the vulnerability analysis and the allocation and implementation of adaptation measures in WP 5. The risk maps will also be used as a basis for risk communication (WP 6).

Achievements in relation to milestones/work plan and intermediate scientific results

In 2023 we acquired additional data sets from our Jordanian partners, e.g. high resolution DEM for Amman and Wadi Musa, high resolution data series from rainfall stations in Wadi Musa, data about infrastructure for Amman.

In the SWP 3.1 – Hazard analysis (“exposure”) we could improve our already existing hydrological and hydraulic models. Especially the spatially distributed results of the hydraulic model HE2D/FOG2D benefit much from the better data base; see e.g. the modelled inundation areas for Wadi Musa with the new Digital Elevation Model (DEM) with a resolution of 2 m compared to the old results with a DEM of ~ 12.5 m in Fig. 7.

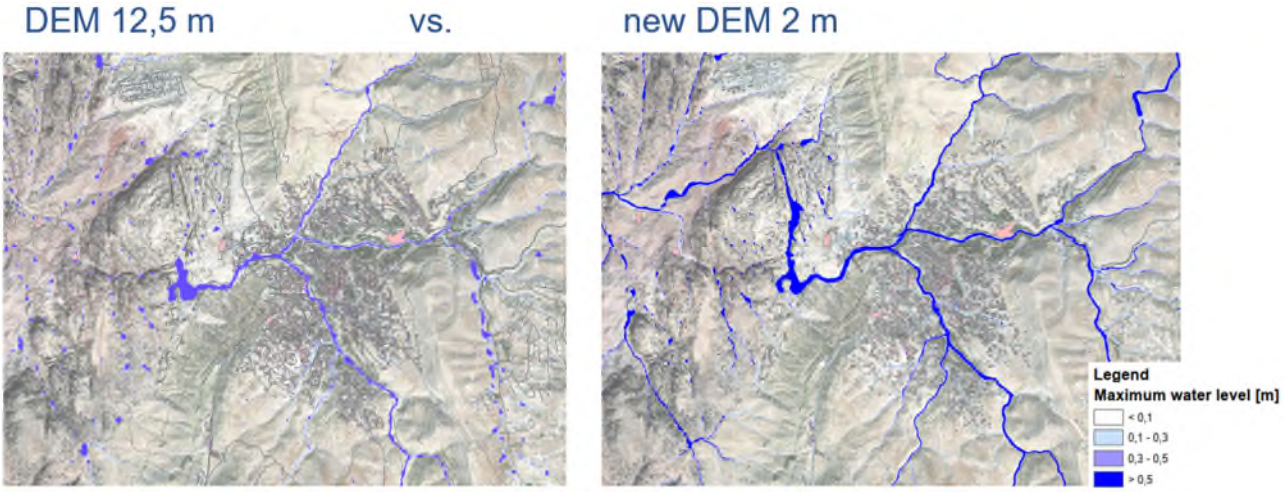

Figure 7. *Results of the hydraulic model HE2D/FOG2D for the area of Wadi Musa / Petra. On the left based on the DEM with a resolution of 12.5 m and on the right based on a high resolution DEM of 2 m.*

For the hydrological models (HEC-HMS and RRI) we have now different setups e.g. using different infiltration modules and different input datasets for Wadi Musa. Through the comparison of model results we can quantify their uncertainties, which is especially important as they are the core for WP 5 and used to quantify the effects of climate and land use and land cover changes (LULCC) as well as possible adaptation measures. About this multi-model approach, we are also working on a scientific publication.

In the SWP 3.2 – Damage potential ("sensitivity") Felix Braun completed his bachelor thesis in which he conducted an analysis of the damage potential for Downtown Amman. We additionally conducted a literature research and stakeholder interviews, and refined and adjusted the first approach using the DWA-M 119 classification. The results were discussed with GAM in an online meeting and are now finalized. As for Wadi Musa we do not have the same broad input data, there the classification is still according to DWA and only using public available OpenStreetMap data.

Another important step was the successful finalization of Ahmad Awad's master thesis on the spatial-temporal dynamics of land use and land cover changes (LULCC) in Amman from past (1968) to present (2021). From this analysis, a mathematical model was setup to predict possible future land cover trends for Amman. The results of the model were refined by integrating existing urban development plans which were identified by means of expert interviews. The result of this thesis and the predicted future land cover changes with its effect to flash floods in Amman, modeled with the hydrological HEC-HMS model, are prepared for a scientific publication. Fig. 8 shows the LULCC analysis of Amman for past (1968), present (2021) and future (2050).

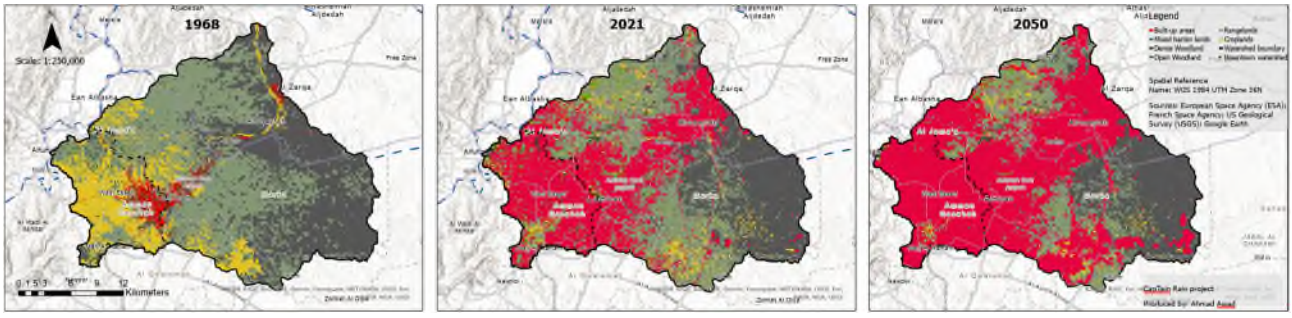

Figure 8. *LULCC analysis for our study region in Amman, Jordan from 1968 to 2050.*

As a combination of the new hazard and damage potential maps we also created flash flood risk maps accordingly for the current state within SWP 3.3 – Identification and assessment of flash flood risk.

To have better common base for discussion we translated the DWA-M 119 and the English version is now available for our Jordanian partners and in review at DWA.

Inter- and transdisciplinary cooperation, highlights and difficulties

With the hydrologic and hydraulic models of WP 3 the scenario analysis in WP 5 will be simulated. To guarantee that the climate input (WP 2) as well as the adaptation measures (WP 4) can be integrated to the different models, WP 3 is in exchange with the two work packages. Several joint WP-meetings took place as well as fruitful discussions in the different project meetings.

WP 3 has the strongest collaborations with GAM, PDTRA and NARC. Their expert input is very valuable e.g. for the future land cover prediction or the assessment of the damage potential. The exchange was further strengthened by on site meetings in Amman and Wadi Musa in January and December 2023. But also, the exchange vial online meetings works well.

The cooperation with the Kyoto University (Dr. Sameh Kantoush) and the German-Jordanian University (Dr. Qasem Abdelal) for our focus area Wadi Musa/Petra continued. The status quo of the work was presented at the ISFF 7 in Tlemcen, Algeria in June 2023.

Future prospects/outlook 2024

The setup of the hydrologic and hydraulic models will be finalized by the beginning of 2024 (Milestone 4). We will then conduct the simulation of the scenarios drafted in WP 5 (rainfall, LULCC, measures).

At the “Tag der Hydrologie” (20.-21.03.2024, Berlin) Clara Hohmann will give an oral presentation on “Hydrological approaches to assess flash flood risks in data scarce and climate-change affected regions like Jordan”. This work comprises mainly the LULCC and rainfall scenario analysis for Amman and is therefore conducted jointly by Hochschule Koblenz, itwh, ISOE and PIK. A short publication will be contributed to the proceedings of the conference. The abstract “Flash flood risk assessment in data scarce regions vulnerable to climate change: Hydrological lessons learnt from Jordan” was accepted as an oral presentation at the 8th IAHR Europe Congress (04.-07.06.2024, Lisbon). Moreover, it is planned to write a scientific publication about our multi-model approach in Petra and another publication about the LULCC and their impacts on flash floods in Amman.

In the final CapTain Rain event in Jordan (planned for June or July 2024) many products of WP 3 will be handed over to the Jordanian partners. The main product is a set of maps (LULCC, hazard, damage potential, risk). To ensure that the results will be used further also the raw results in GIS format as well as the underlying retrieved data will be shared.

W 4 Adaptive capacity

WP 4 “Adaptive capacity” deals with the potential or capability of a system to adapt to the risk of flash floods. The perception and knowledge of the local population will be analyzed to identify knowledge gaps and recommend knowledge transfer. Appropriate and innovative measures to mitigate flash flood risks will be identified with the use of GIS-based participation methods. The measures and strategies of adaptive capacity of this project can be applied to other areas and therefore, with the help of technology, form an innovative foundation to reduce the risk of flash floods. The SWP 4.1 “**Local (practical) knowledge**” addresses the investigation and analysis of the perception of flash flood hazards by the

residents as well as local (practical) knowledge including decision making for protective measures. Measures for the retention, safe discharge, storage and use of heavy rainfall are identified and evaluated in SWP 4.2 "**Prevention of (urban) flash flood damage**". These measures can be related either to infrastructure, to the drainage system or to the catchment areas and they can be of technical, institutional or social nature. For areas with high land use pressure, the concept of multifunctional land use for heavy rainfall prevention serves as an interesting option. For the joint assessment of promising adaptation measures with local stakeholders and to provide tools for local decision-making, participatory GIS methods will be tested and implemented.

Achievements in relation to milestones/work plan and intermediate scientific results

Based on the identification of planning goals and possible measures during the stakeholder workshop in January 2023, WP 4 conducted a **potential analysis within GIS and additional online planning workshops** for the allocation of measures. Results from WP 3 (flash flood risk) and WP 5 (vulnerability) have been used to identify suitable locations and areas for implementing different measures according to the categories established in the measures catalogue. The GIS-based integration also involved the establishment of shape files for most relevant measures from the measure catalogue. Regions of interests for the planning of the implementation of measures with local stakeholders ("focus areas") were selected at different spatial scales to reflect different requirements in urban space with regard to measures. The regions of interests were been divided in:

- Catchment or sub-catchment
- Districts
- Housing and Neighbourhood
- Public space (park, parking lots, conversion area)

Together with the Jordanian project partners a more detailed analysis of the regions of interest in terms of their suitability for specific measures and the combination of measures were conducted during online planning workshops. Potential measures were selected and located in the areas in a joint participatory planning process (online) by the interactive tool Concept Board. Through recommendations and location specific remarks from the Jordanian project partners involved further risk assessments and points of interests were elaborated. Possibilities of up-scaling the results from the regions of interest to the whole watershed of Amman were evaluated and discussed especially with AP 3.

The preferred measures for blue and green infrastructure, water harvesting, object protection and structural measures for conducting water flows during heavy rains were selected jointly with Jordanian partners. **Info cards** were designed for each of these measures to help local urban planners in Jordan to gain a fast overview about the major characteristics of the measures to make adequate decisions when selecting them. This is especially helpful as not all professionals involved in such a planning process are familiar with all measures due to their different professions. The info cards help for a transparent planning process were the different persons involved can act on Eye-level independent of their personal expertise and are an important product of AP 4 (Fig. 9).

During the third stakeholder workshop **possible measure scenarios** were discussed mainly with GAM members. GAM described their "business as usual" scenario which includes constructional works within the city to manage the stormwater. Mentioned measures were the expansion of box culverts, the diversion of wadis e.g. in Marj al-Hamam and the building of big water storages e.g. three reservoirs in Abdoun. All these measures are very cost-intensive. For the "best practice" scenario possible measures mentioned were green infrastructure, urban gardening, bio retention, bioswales and small dams to capture and retain the water. However, the implementation of such measures is hampered by lacking

budget and land scarcity within the city of Amman. GAM supports these types of measures and nature-based solutions, but emphasizes that awareness needs to be raised among the local population to ensure the implementation of measures on private land. GAM is already working with tax breaks and penalties as well as educational measures to incentivize measures that people can implement on their private land.

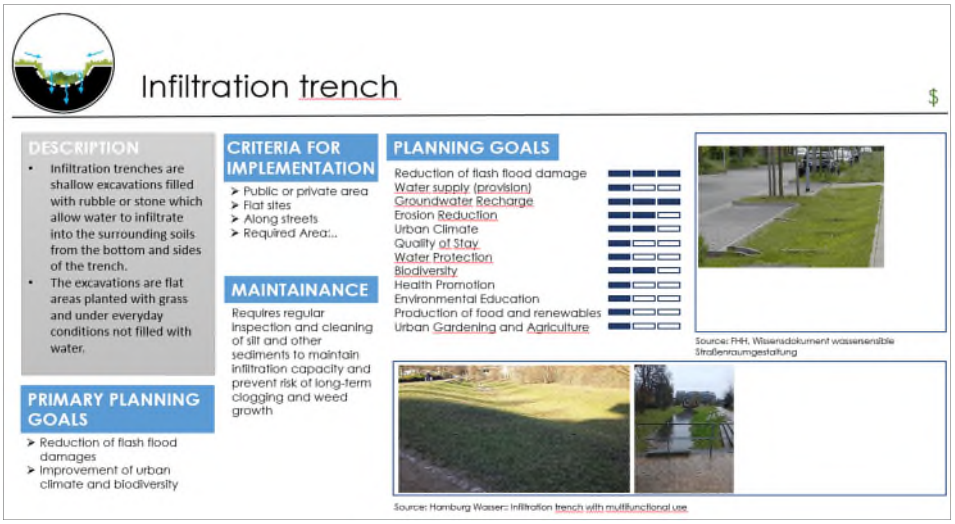

Figure 9. *Example of the final design of the info cards and symbols for selected Measures for Blue Green Infrastructure*

Additional on-field surveys and semi-structured interviews with residents in Amman (n = 17) were conducted in 2023 to gather information on how local people perceive, understand and respond to flash floods. The structured questionnaire included questions on personal information, knowledge and local perception on flash floods events, drivers and causes of flash floods and knowledge and experience with flash flood adaptation strategies. The interviews were recorded, partly transcribed and analyzed.

Inter- and transdisciplinary cooperation, highlights and difficulties

With the help of the rainfall-runoff simulations and flash flood risk mapping prepared in WP 3, suitable locations for the implementation of possible adaptation measures were identified and located together with the local actors in WP 4. Participatory GIS methods were used that allowed to better communicate and discuss the results of WPs 3-5 with local stakeholders. The results of the planning workshops on measures identification and allocation were used to draft the measures scenarios in WP 5. The analysis on risk perception in SWP 4.1 provides the basis for establishing user-friendly early warning systems in SWP 6.2. On the Jordanian side, this WP is supported in particular by NARC, GAM and PDTRA, which contribute their knowledge and experience in dealing with (traditional) adaptation strategies. Further activities comprise:

- Project meeting, regular meetings with WP3 and WP5 to discuss WP specific-results, synergies and integration of data and results
- Stakeholder workshops and further online planning workshops in June and November 2023
- Preparation of the final stakeholder workshop in January 2023 in Amman.

Future prospects/outlook 2023

- Planning workshop with Jordanian partners in Amman and Wadi Musa using the multitouch table for participatory GIS application in urban planning

- Final selection and localization of measures (Verification on site)
- Capacity building on interdisciplinary and integrated planning in terms of climate adaptation and infrastructure coordination
- Qualitative and quantitative evaluation of the different effects of the measures in relation to the planning and developing goals
- Guideline/Policy brief for promising adaption strategies

WP 5 "Vulnerability"

WP 5 combines the results of the other WPs to perform an integrated vulnerability analysis and assessment in close collaboration with relevant stakeholders (Fig. 10). We use the social-ecological vulnerability concept as common framework to assess the different vulnerability components, exposure, sensitivity and adaptive capacity, from an integrated social-ecological perspective. Besides the vulnerability assessment for the current situation, we also explore vulnerability for possible future pathways with regard to climate and land cover changes (exposure and sensitivity), as well as measures to decrease flash flood damages (adaptive capacity). Using a scenario analysis, the effects of climate (WP 2) and land use changes (WP 3), as well as measures to decrease flash flood damages (AP 4) are simulated with hydraulic and hydrologic models of WP 3 and assessed using vulnerability indicators. Different options are investigated with the aim of decreasing vulnerability. The simulated scenarios are discussed and assessed with local stakeholders. The results of the model-based scenarios serve as a decision support tool for local stakeholders in urban planning and the resulting recommendations for action will be published as manuals, guidelines or policy briefs (WP 6.2).

Figure 10. *Overview of the integrated vulnerability assessment cycle.*

Achievements in relation to milestones/work plan and intermediate scientific results

In 2023, the **social-ecological vulnerability assessment framework** for CapTain Rain was finalised: Our approach is based on the framework promoted by the Intergovernmental Panel on Climate Change (IPCC), which has been widely adopted for vulnerability assessments. In this IPCC definitions, vulnerability is understood as a function of exposure, sensitivity and adaptive capacity. WP 5 conducts a spatial-explicit social-ecological vulnerability analysis (maps), which also has a flexibility in its overall representation by (eventually) incorporating non-spatial indicators in an integrated assessment. Vulnerability is assed at different temporal scales for the past (inherent vulnerability), present (current

vulnerability) and for future scenarios. For the different vulnerability components (exposure, sensitivity and adaptive capacity) multiple social, ecological and physical indicators (domains) are used for their assessment.

For the selection of **vulnerability indicators**, a literature survey was conducted to have an overview on the state of the art. The relevant disciplinary results of AP 2, 3 and 4 were used as base data in combination with additional socio-economic data to calculate social, ecological and physical vulnerability indicators for each component. For this, spatial analysis with GIS and statistical procedures (data transformation, PCA, etc.) were performed to reduce data dimensions. So far, the vulnerability components sensitivity and exposure have been analysed for the current situation (see Figure 11). For exposure, which is calculated in relation to the distance of flood prone areas, stakeholder input was needed for the selection of a suitable distance measure. In order to better adapt the sensitivity assessment of infrastructure and buildings (damage potential) to local conditions, we have included the assessment of Jordanian experts and partners on damage potential and adapted the DWA categories for the assessment of damage potential accordingly in consultation with the partners. The vulnerability component adaptive capacity needs to be further elaborated due to the lack of socio-economic data. Here, auxiliary variables are used to estimate the local awareness and knowledge, and the potential to implement measures (e.g. via availability of household assets).

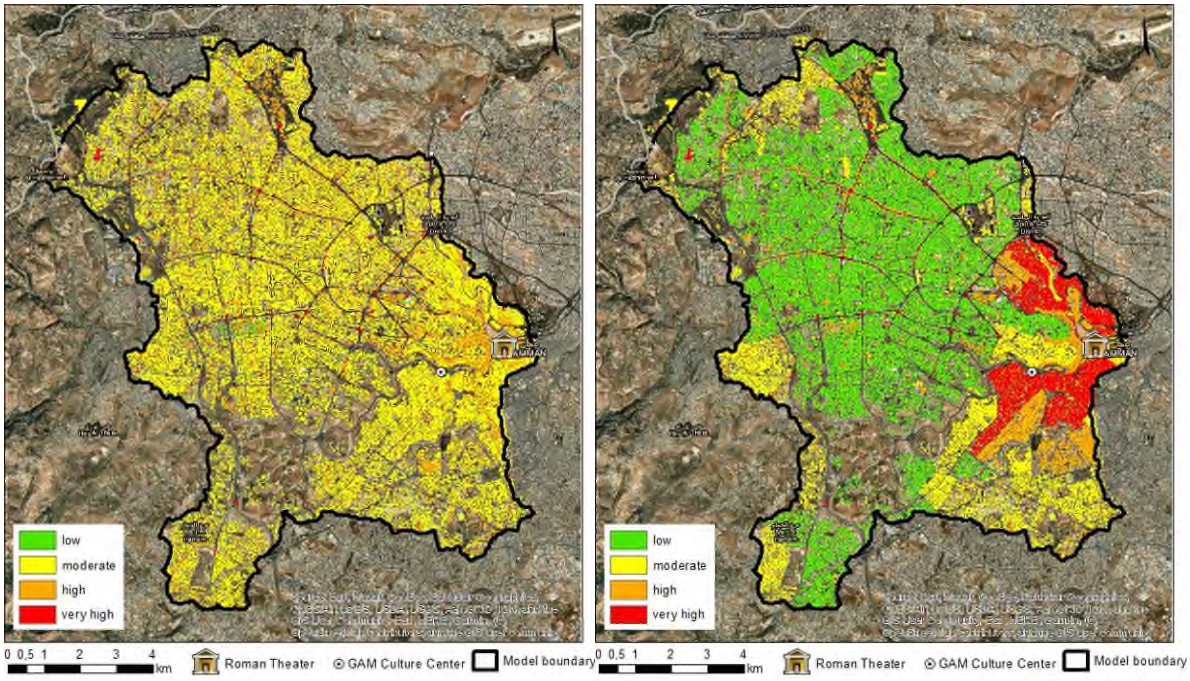

Figure 11. Examples of vulnerability maps for Amman watershed - left: sensitivity of infrastructure (based on damage potential); right: sensitivity of inhabitants (based on demographic & economic dependency; Marshall et al. 2017).

Based on the results of the second stakeholder workshop, the CapTain Rain team selected several **possible future scenarios** combining climate changes (changes in heavy rainfall events), land cover changes (for Amman in 2050) and different combinations of measures according to area types that have the potential to decrease flash flood damages (e.g. business as usual or best practices). To decrease the complexity not all possible scenarios will be simulated. Here, we will focus on the combinations, which are most important and useful for the stakeholders. This was done during the **third stakeholder workshop**, were possible scenarios were presented and jointly discussed with the Jordanian stakeholders. Based on these results four contrasting possible future scenarios were prioritized and

adapted, which will then be simulated using hydraulic and hydrological modelling and assed. Another important outcome of the third stakeholder workshop was the joint agreement on vulnerability indicators and their weighing for the integrated assessment. During group work, participants evaluated the relative importance of the different vulnerability indicators. This was done by using the analytic hierarchy process (AHP). Every participant filled a matrix with pairwise comparisons of the importance of vulnerability indicator domains. Based on the given evaluations the weight for each domain is calculated.

Inter- and transdisciplinary cooperation, highlights and difficulties

The potentials of the promising adaptation strategies for urban and rural areas identified in WP 4 will be analysed in a scenario analysis in WP 5. The modelling tools required for this are provided by WP 2 and WP 3. From the integrated assessment in WP 5, recommendations for action and measures are derived and the all results (including maps and models) are a prominent product in the dissemination strategy of WP 6.

In this WP, all partners are involved. In the framework of the stakeholder workshop "Validation and Scenario Development", the identification of promising adaptation strategies for the scenario analysis (scenario development) took place jointly with Jordanian partners and stakeholders. The presentation and discussion of the vulnerability and scenario analysis was successfully conducted in the subsequent third stakeholder workshop "Assessment and Recommendations for Action".

Future prospects/outlook 2024

- Further elaboration of the vulnerability component adaptive capacity by using auxiliary variables to estimate the local awareness and knowledge, and the potential to implement measures (e.g. via availability of household assets).
- Analysis of the AHP results from the third stakeholder workshop and weighing of vulnerability indicators (domains). Results will be used to also display an integrated vulnerability indicator combining all domains and components.
- Finalization of the vulnerability assessment for the selected scenarios in Amman (simulation using hydraulic and hydrological modelling and integrated assessment using vulnerability indicators)
- Finalization of the vulnerability assessment for Wadi Musa (current situation).
- Display results in vulnerability maps, radar charts showing the results of the different indicators, as well as an integrated vulnerability indicator using the weights of the AHP approach.
- Discussion and validation of results with Jordanian partners
- Preparation of recommendations and finalization of the WP 5 products: maps and model-based scenarios (incorporate maps on multitouch table and WebGIS application of GAM) and recommendations (fact sheets, report and scientific publication).

WP 6 “Climate Services & Knowledge Transfer”

WP 6 "Climate Services & Knowledge Transfer" focuses on providing recommendation for climate services (e.g. early warning systems) for climate and flash flood-related decision-making as well as the communication of risks and impacts of flash floods. The **SWP 6.1 “Recommendations for early warning systems and demonstrator”** analyses the weaknesses and strengths of existing EWS including their underlying data sources, methodology and dissemination tools, and develops recommendations for a EWS adapted to the needs of the users. The user-friendliness of the existing early warning system in Petra is assessed and evaluated through expert interviews and focus group

discussions with local stakeholders (What information should be included? What media channels should be used? Do warnings reach all people at risk? Are the risks and warnings understood? Are the warnings clear and usable?), in order to be able to work out recommendations for the development of early warning apps for the population. This will form the basis for the design and implementation of an appropriate service as a demonstrator. The transfer of scientific results and climate services into practice is conducted by means of target group-oriented dissemination strategies in **SWP 6.2 "Knowledge transfer into practice".** Comprehensibility and user-friendliness form the basis for well-prepared results, which are needed by the individual actors and decision-makers to facilitate decision-making processes and to be able to initiate climate-relevant changes. In this context, capacity development is crucial for fostering individual competencies that enable stakeholders to act in a way that is both responsible and self-dependent. Capacity development is carried out at different levels with formats specifically tailored to stakeholders and supports the training of local decision-makers and users in scientific and technical competencies to use the climate services established in CapTain Rain (e.g. EWS and risk maps).

Achievements in relation to milestones/work plan and intermediate scientific results

The development of the **demonstrator for the Jordan Water & Weather Portal** focused mainly on the further development of the data storage and provision technologies on which the demonstrator is based. These were developed based on the results of the research project "Sustainable strategies and technologies for flood risk management in arid and semi-arid areas (HOWAMAN) - sub-project: Platform for flood forecasting, early warning and end-user communication" (FKZ: 13N15183). The demonstrator was designed to be more efficient and performant in order to make the excessively large volumes of weather forecast grid data available to the end user quickly and reliably via an internet browser. The monitoring network of the Petra Development & Tourism Region Authority (PDTRA) was integrated as a new real-time data source - data from several weather stations in the Petra region is now displayed in the demonstrator and used to identify heavy rainfall events. Furthermore, additional historical weather data from the Ministry of Water and Irrigation (MWI) was imported into the system.

Functional enhancements include the "nowcasting" of precipitation estimates based on satellite remote sensing data. Short-term forecasts are produced based on the directions of precipitation fields. In contrast to conventional weather forecasts, this approach can also predict small-scale heavy rainfall events of up to one hour. This nowcasting method was developed as part of the HOWAMAN project and has now been implemented for the Jordanian territory. Normally, nowcasting is performed using radar-based data, which was for our study region, however, not feasible. Using satellite data as precipitation estimates from radar in Amman would improve the system.

In addition, the identification of heavy rainfall events in Amman and Petra was implemented using nowcasting (via satellite remote data Eumetsat H SAF) and weather forecasts (via the ARPEGE, German Weather Service ICON and European Center for Medium-Range Weather Forecasts HRES models). Local project partners are now warned by e-mail if area-specific threshold values are exceeded for the Amman sub basins, which is based on three different forecast models (ARPEGE, DWD ICON and ECMWF).

To identify recommendations for the implementation (Amman) and/or improvement (Wadi Musa) of early warning systems (EWS), expert interviews have been conducted with JMD (Amman) and PDTRA (Wadi Musa). The interview results were analysed and possible recommendations were discussed with Jordanian Partners.

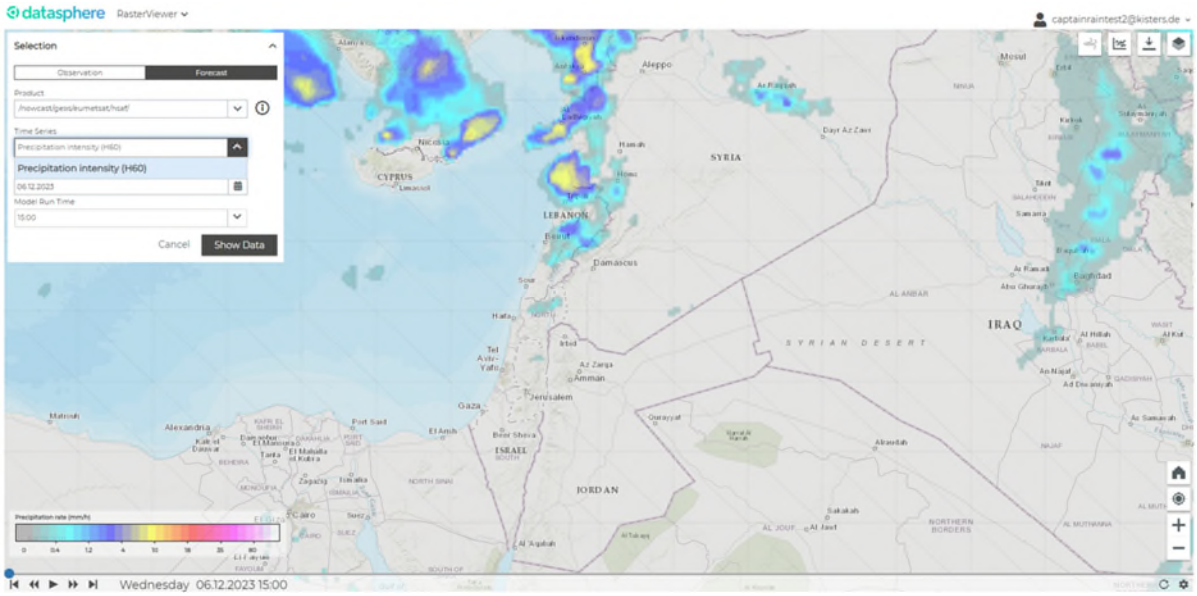

Figure 12. *Screenshot of the demonstrator for the Jordan Water & Weather Portal showing nowcasted rainfall for all of Jordan.*

Based on the results of the second and third stakeholder workshop the **dissemination plan for the CapTain Rain results (SWP 6.2)** has been refined, by developing target group-specific formats for decision-makers and practitioners. This also includes contributions to capacity building. Contributions are made here by all project partners. For the dissemination of products and results different formats will be used comprising fact sheets, an online Wiki with a description of the CapTain Rain products, reports, scientific publications and a data repository for the transfer of spatial data/ maps and models (Cloud data exchange platform, climate service portal of PIK, Multi touch table, WebGIS of local partners).

Inter- and transdisciplinary cooperation, highlights and difficulties

Due to a cyberattack on the IT system of KISTERS AG and delays in the formal process of the cooperation agreements, various planned activities of the project could only be started late in 2023. However, this was made up for in 2023 and the project is now on schedule.

The work on the integration of data in the demonstrator will continue in 2024 in close collaboration with AP 2 and the Jordanian partners (JMD, MWI and PDTRA). The dissemination of the demonstrator has already been started through the creation of accounts that allow our German and Jordanian partners to access visualize and extract it in order to integrate it with their own processes. Training and personal advice will be continue sly offered to foster the use of the demonstrator use.

For the dissemination of the project results, all relevant CapTain Rain results are included and processed in a target group-oriented manner based on the results of the stakeholder analysis and stakeholder workshops in SWP 1.1.

Future prospects/outlook 2024

- Additional in-person, hands-on workshops on the usage of the Early Warning System demonstrator in Jordan;
- Analysis of the interviews to investigate the local perception and knowledge gaps concerning EWS

- Development of recommendations for the establishment/improvement of EWS in Amman and Wadi Musa and finalization of fact sheets
- Refinement of the dissemination plan to ensure the transfer of CapTain products to target groups until July 2024.

Supervised PhD, Master and Bachelor thesis in 2023

- Ahmad Awad, Master thesis “Analysis of the spatial-temporal dynamics of land-use changes using a mixed-method approach: A case study from Amman, Jordan”, Technical University of Munich, supervision: Dr. Isabel Augenstein, external supervision: Dr. habil Katja Brinkmann, 14.02.2023
- Felix Braun, Bachelor thesis “Analyse von Schadenspotenzialen bei Sturzfluten am Beispiel Downtown in Amman“, Koblenz University of Applied Sciences, supervision: Prof. Dr. Dörte Ziegler, Dr. Clara Hohmann and Christina Maus, 06.02.2023

List of publications and conference contributions in 2023

- Awad, A., Brinkmann, K., Hohmann, C., Abu Hamour, W. and Alnaimat, M., 2023: How have land cover changes and urbanization contributed to the flash flood risk in the city of Amman? An analysis of past and future trends. Poster presentation held at the 7th International Symposium on Flash Floods in Wadi Systems (ISFF7) in Tlemcen, Algeria, 5.-7.06.2023.

- Fallah, B., Russo, E., Menz, C. Hoffmann, P., Didovets, I., and Hattermann, F. F, 2023: Anthropogenic influence on extreme temperature and precipitation in Central Asia. Sci Rep 13, 6854, https://doi.org/10.1038/s41598-023-33921-6.

- Fallah, B., Menz, C., Russo, E., Harder, P., Hoffmann, P., Didovets, I., and Hattermann, F. F., 2023: Climate Model Downscaling in Central Asia: A Dynamical and a Neural Network Approach, Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2023-227, in review.

- Hoffmann, P., Brum, M., Alrahaife, M. and Hohmann, C., 2023: Causal linkage between extreme rainfall in Jordan and large scale circulation patterns. Poster presentation held at the 7th International Symposium on Flash Floods in Wadi Systems (ISFF7) in Tlemcen, Algeria, 5.-7.06.2023.

- Hoffmann, P. 2023: A contextualization of heavy rainfall events in climate forecasts: A case study for Amman in Jordan. Oral presentation held at the EMS Annual Meeting 2023 in Bratislava, Slovakia, 4.-8.09.2023. EMS2023-554, https://doi.org/10.5194/ems2023-554.

- Hohmann, C., Maus, C., Ziegler, D., Kantoush, S., Maßmann, S. and Abdelal, Q., 2023: Multi-model approach for flash flood modelling in data- and water-scarce regions like Jordan. Oral presentation held at the 7th International Symposium on Flash Floods in Wadi Systems (ISFF7) in Tlemcen, Algeria, 5.-7.06.2023.

- Maus, C., Hohmann, C., Ziegler, D. and Maßmann, S., 2023: Modelling flash floods in data- and water-scarce regions like Jordan - a multi-model approach. Poster presentation held at the Tag der Hydrologie in Bochum, Germany, 21.-23.03.2023.

List of project meetings and workshops

- 30.01.2023 Second CapTain Rain stakeholder workshop in Amman
- 06.04.2023 Meeting German project partners, online
- 27.04.2023 Steering committee meeting, online
- 06.07.2023 Meeting German project partners, online
- 19.-20.09.2023 Meeting German project partners, Potsdam and online
- 11.10.2023 Steering committee meeting, online
- 11.12.2023 Third CapTain Rain stakeholder workshop in Amman
- 13.13.2023 Additional stakeholder workshop in Wadi Musa