sPATE

Newsletter

Space-Time Dynamics of Extreme Floods

Edition 10

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The final months

Dear colleagues and followers of the SPATE research unit,

Full of anticipation and excitement, but also with a teary eye, we look forward to the upcoming last six months of our research group. After six years of intensive cooperation, interesting exchanges and many meetings, the SPATE research group will come to an end at the end of May 2023. Already from today's perspective, we can be more than proud of everything we have achieved. Scientists from our research group have won several prizes, have been involved in more than 140 publications in the six years and have given countless presentations at international conferences. We are also particularly pleased that a total of three of our young scientists have received their doctorates and two staff members have habilitated. But these successes are of course no reason for us to rest now. On the contrary, many final collaborations are underway right now, which build on the previous results. And a joint final publication of all sub-projects is also being prepared.

However, we are particularly looking forward to our final symposium. In order to make our research results available to all scientists, we have decided to present them to all interested parties at a large final symposium entitled "The Future of Flood Research - Expectations on Scientific Developments in the Next 10 Years". In addition, we are pleased to have many invited speakers, e.g. Elena Volpi, Attilio Castellarin, Richard Vogel, Jery Stedinger, Manuela Brunner, Pedro Chaffe, Christian Onof and Ashish Sharma. The symposium offers a great opportunity to discuss current developments and future challenges in flood research. Of course, the symposium is open to all interested parties and we do not charge a registration fee. It will take place at April 23, 2023 (right before the EGU General Assembly) at the Festsaal of TU Vienna, Austria. More information and the full programme can be found on our website and in the announcement in this newsletter:

https://www.spate.ruhr-uni-bochum.de/symposium.html.en

We look forward to welcoming many participants.

But we do not only want to look into the future. In this issue of the newsletter, we show once again how much is being done by the scientists in our research group. Among other things, a joint paper on the development of heavy tails in hydrological time series has been produced, which we would like to present in detail here. We hope you enjoy reading.

On behalf of the whole SPATE-project, with kind regards,

Svenja Fischer and Andreas Schumann

Members of the SPATE-project

Dr. Svenja Fischer, Prof. Dr. Andreas Schumann
Subproject 1 (Ruhr-University Bochum)

Prof. Dr. Bodo Ahrens, Mostafa Hamouda
Subproject 2 (Goethe-University Frankfurt)

Dr. Sergiy Vorogushyn, Prof. Dr. Bruno Merz, Dr. Björn Guse, Elena Macdonald, Luzie Wietzke
Subproject 3 (GFZ Potsdam)

Prof. Dr. Ralf Merz, Dr. Larisa Tarasova
Subproject 4 (UFZ Halle/Saale)

Prof. Dr. András Bárdossy, Dr. Jochen Seidel, Faizan Anwar
Subproject 5 (University of Stuttgart)

Prof. Dr. Günter Blöschl, Dr. Miriam Bertola, Dr. David Lun
Subproject 6 (Technical University of Vienna)

Prof. Dr. Uwe Haberlandt, Dr. Anne Bartens, Maysaa Abdelmajid, Ross Pidoto, Luisa Thiele
Subproject 7 (Leibniz University Hannover)

Members of the research unit SPATE at the SPATE-Meeting in Hannover, April 2022.

The Future of Flood Research - Expectations on Scientific Developments in the Next 10 Years

Final Symposium of the DFG Research Unit „Space-time Dynamics of Extreme Floods"

TU Vienna, 23 April 2023, Festsaal, Karlsplatz 13, Vienna, Austria

Starting at 1st of June 2017 and ending 31st of May 2023, the Research Unit of the German Research Foundation (DFG) explored extreme flood processes. The main objective was to understand the processes leading to extreme river floods and how these evolve in space and time. Over 6 years this Research Unit followed the natural and coherent approach of exploring extreme flood processes along the following axes of scales:

(i) Event scale processes: Here the hydrometeorological causes of the most extreme floods, the interactions of the component processes and how the processes change when moving from small to extreme events were explored.

(ii) Spatial (regional) scale variability: The spatial relationships of river flooding as a result of the interplay of the spatial patterns of atmospheric, watershed, and river system processes were analyzed.

(iii) Temporal (decadal) scale variability: Periodic climatic processes may lead to long-term variability of floods over decades and centuries. Observed flood changes were formally attributed to their drivers and future changes in a process-based way were anticipated.

(iv) Uncertainty and predictability: Given the many non-linearities involved in the generation of extreme floods, predicting them in deterministic and probabilistic frameworks involves a range of uncertainties. With combining weather generators with hydrological models and new flood statistical tools these uncertainties were characterized.

The main results of these research activities, which were derived in a close cooperation of 7 research institutes in Germany and Austria will be presented and discussed in the of this meeting.

The second part gives an outlook on promising developments in flood research that will expand the knowledge base on flood events and their impacts in the coming years. Experienced and young scientists from different parts of the world present their developments and approaches. During a panel discussion, all participants are invited to share their ideas.

As a result of this event, young scientists in particular should be encouraged to address the extremely challenging topic of extreme floods and to make their contributions to flood research here in the next ten years.

Understanding Heavy Tails of Flood Peak Distributions

Floods often come as a surprise. A recent example are the devastating floods in Western Europe in July 2021. For a number of catchments, the flood peak was several times higher than the flood of record observed during the last decades. The occurrence of such an event is not only counterintuitive, it is also very unlikely if the extreme value behaviour is predicted by commonly used distributions that have exponential asymptotic behaviour, such as the Gumbel distribution. However, if the underlying probability distribution has a heavy tail, its occurrence is less unlikely. A heavy upper tail implies that the extreme values are more likely to occur compared to distributions with exponential asymptotic behaviour. The heaviness of the tails of flood peak distributions is very difficult to predict, which may lead to unnecessarily high flood damage. Despite its high importance, the literature on the heavy tail behaviour of flood distributions is rather fragmented.

In the joint review article “Understanding Heavy Tails of Flood Peak Distributions” published in Water Resources Reserach, we summarize the knowledge on heavy flood tails and provide a coherent overview of the processes causing heavy tails and the implications for science and practice. Analyses of observed flood time series often suggest the presence of heavy tails. However, heavy-tail behaviour is not only widespread in flood peak data, but also in other variables related to flooding, for instance in annual maximum daily precipitation and flood loss. We propose nine hypotheses on the mechanisms causing heavy tails in flood peak distributions related to processes in the atmosphere, the catchment, and the river system. We then discuss to which extent the current knowledge supports or contradicts these hypotheses, and we review the degree to which the heaviness of the tails can be predicted from process knowledge and data. For instance, we find a high plausibility for the hypothesis ‘Mixture of flood types generates heavy flood tails’, as there is a clear understanding how mixtures of flood types can generate heavy tails: Firstly, if one of the component distributions, representing one flood type, is heavy-tailed, then the mixture distribution tends to be heavy-tailed. Secondly, if there is a different process that occurs very rarely, but generates much higher peaks, the distribution of the superposition of both processes can be heavy-tailed, even when distributions of both regular floods and rare floods are light-tailed. The evidence for this hypothesis is limited, however, as there are hardly any studies that explicitly investigate the relation between the mixture of flood types and flood tails.

Finally, we recommend further research towards testing the hypotheses and improving the prediction of heavy tails. We recommend four guiding questions when confronted with the challenge of estimating tail heaviness and designing flood protection. For instance, we need to understand: Which processes lead to floods and affect flood peaks in the catchment under study? Do these processes favour heavy-tailed flood peak distributions? For example, catchments where flood generation is dominated by snowmelt tend to show lighter tails compared to catchments with rainfall-driven floods, and climatic regions whose flood generation processes are characterized by stronger non-linearity tend to show heavier flood tails. By understanding the factors that can generate heavy-tail behaviour, hydrologists will be better able to predict when heavy-tailed behaviour could occur and reduce surprise.

More details can be found in the publication of Merz et al. (2022).

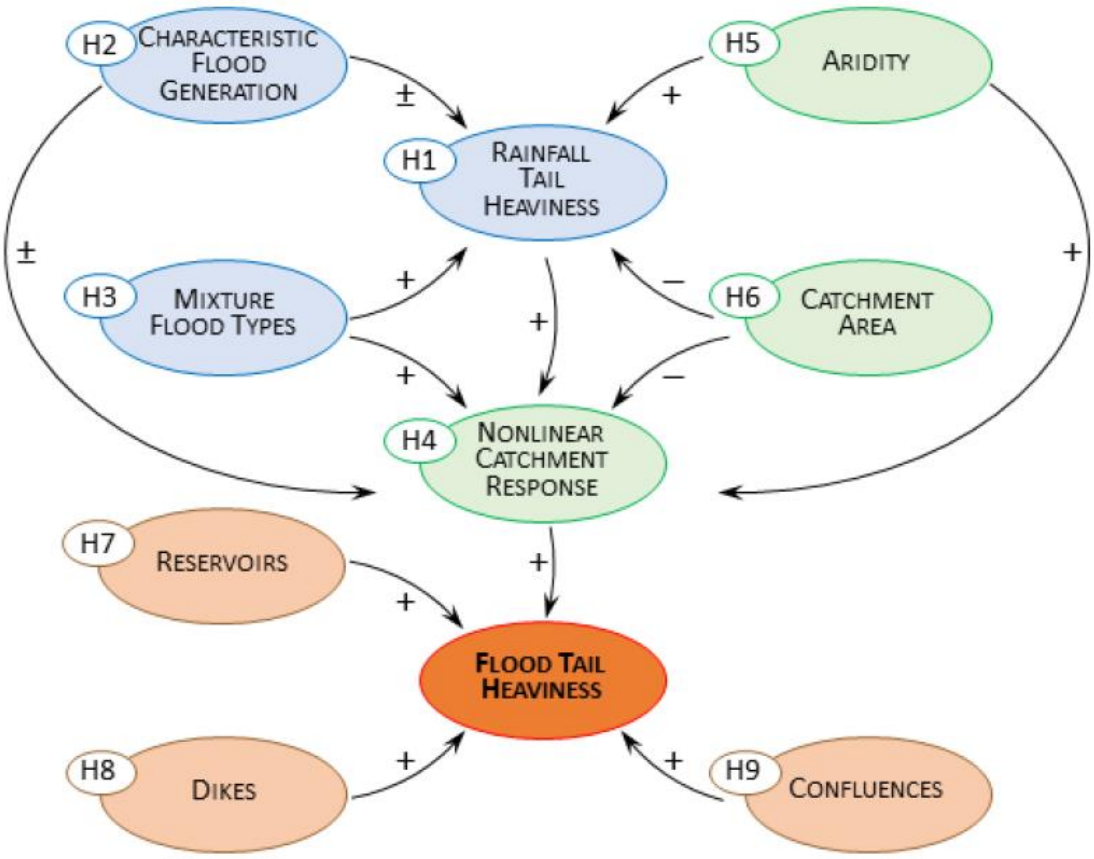

Figure from Merz et al. (2022): Relations between the nine hypotheses. + and − arrows represent positive/negative cause-effect relations. ± represents an effect that can work positively or negatively. The arrows should not be understood as equally substantiated. Colors denote the compartments atmosphere (blue), catchment (green) and river network (brown).

Reference:

Merz, B., Basso, S., Fischer, S., Lun, D., Blöschl, G., Merz, R., Guse, B., Viglione, A., Vorogushyn, S., Macdonald, E., Wietzke, L., Schumann, A. (2022). Understanding Heavy Tails of Flood Peak Distributions. Water Resources Research, 58(6), e2021WR030506. doi:https://doi.org/10.1029/2021WR030506

Publications

1) Publications in journals

Published since last newsletter:

Apel, H., Vorogushyn, S. (SP3), Merz, B. (SP3) (2022): Brief communication: Impact forecasting could substantially improve the emergency management of deadly floods: case study July 2021 floods in Germany. - Natural Hazards and Earth System Sciences (NHESS), 22, 9, 3005-3014. https://doi.org/10.5194/nhess-22-3005-2022

Brunner, M. I., Fischer, S. (SP1) (2022): Snow-influenced floods are more strongly connected in space than purely rainfall-driven floods. Environ. Res. Lett. 17 104038.

Kreibich, H., Loon, A. F. V., Schröter, K., Ward, P. J., Mazzoleni, M., Sairam, N., Abeshu, G. W., Agafonova, S., AghaKouchak, A., Aksoy, H., Alvarez-Garreton, C., Aznar, B., Balkhi, L., Barendrecht, M. H., Biancamaria, S., Bos-Burgering, L., Bradley, C., Budiyono, Y., Buytaert, W., Capewell, L., Carlson, H., Cavus, Y., Couasnon, A., Coxon, G., Daliakopoulos, I., de Ruiter, M. C., Delus, C., Erfurt, M., Esposito, G., François, D., Frappart, F., Freer, J., Frolova, N., Gain, A. K., Grillakis, M., Grima, J. O., Guzmán, D. A., Huning, L. S., Ionita, M., Kharlamov, M., Khoi, D. N., Kieboom, N., Kireeva, M., Koutroulis, A., Lavado-Casimiro, W., Li, H.-Y., LLasat, M. C., Macdonald, D., Mård, J., Mathew-Richards, H., McKenzie, A., Mejia, A., Mendiondo, E. M., Mens, M., Mobini, S., Mohor, G. S., Nagavciuc, V., Ngo-Duc, T., Huynh, T. T. N., Nhi, P. T. T., Petrucci, O., Nguyen, H. Q., Quintana-Seguí, P., Razavi, S., Ridolfi, E., Riegel, J., Sadik, M. S., Savelli, E., Sazonov, A., Sharma, S., Sörensen, J., Souza, F. A. A., Stahl, K., Steinhausen, M., Stoelzle, M., Szalińska, W., Tang, Q., Tian, F., Tokarczyk, T., Tovar, C., Tran, T. V. T., Huijgevoort, M. H. J. V., van Vliet, M. T. H., Vorogushyn, S. (SP3), Wagener, T., Wang, Y., Wendt, D. E., Wickham, E., Yang, L., Zambrano-Bigiarini, M., Di Baldassarre, G., Blöschl, G. (SP6) (2022): The challenge of unprecedented floods and droughts in risk management. - Nature, 608, 80-86. https://doi.org/10.1038/s41586-022-04917-5

Lun, D. (SP6), Fischer, S. (SP1), Viglione, A. (Mercator-fellow), and Blöschl, G. (SP6) (2022): Significance testing of rank cross-correlations between autocorrelated time series with short-range dependence. Journal of Applied Statistics. https://doi.org/10.1080/02664763.2022.2137115.

Merz, B. (SP3), Basso, S., Fischer, S. (SP1), Lun, D. (SP6), Blöschl, G. (SP6), Merz, R. (SP4), Guse, B. (SP3), Viglione, A. (Meractor-fellow), Vorogushyn, S. (SP3), Macdonald, E. (SP3), Wietzke, L. (SP3) and Schumann, A. (SP1) (2022): Understanding heavy tails of flood peak distributions. Water Resources Research 58, e2021WR030506. https://doi.org/10.1029/2021WR030506

Merz, R. (SP4), Miniussi, A., Basso, S., Petersen, K., and Tarasova, L. (SP4) (2022): More Complex is Not Necessarily Better in Large-Scale Hydrological Modeling: A Model Complexity Experiment across the Contiguous United States, Bulletin of the American Meteorological Society, 103(8), E1947-E1967.

Pidoto, R. (SP7), Bezak, N., Müller-Thomy, H., Shehu, B., Callau-Beyer, A. C., Zabret, K., and Haberlandt, U. (SP7) (2022): Comparison of rainfall generators with regionalisation for the estimation of rainfall erosivity at ungauged sites, Earth Surf. Dynam., 10, 851–863, https://doi.org/10.5194/esurf-10-851-2022.

Vorogushyn, S. (SP3), Apel, H., Kemter, M., Thieken, A. H. (2022): Analyse der Hochwassergefährdung im Ahrtal unter Berücksichtigung historischer Hochwasser. Hydrologie und Wasserbewirtschaftung, 66(5), 244-254, https://doi.org/10.5675/HyWa_2022.5_2

Accepted:

Fischer, S. (SP1), Lun, D. (SP6), Schumann, A. (SP1), Blöschl, G. (SP6) (2022): Detecting flood-type-specific flood-rich and flood-poor periods in peaks-over-threshold series with application to Bavaria (Germany). Stochastic Environmental Research and Risk Analyses.

Pre-Prints:

Miniussi, A., Merz, R. (SP3), Kaule, L., Basso, S. (2022): Identifying discontinuities of flood frequency curves. DOI: 10.1002/essoar.10507563.3.

Tarasova, L. (SP3), Lun, D. (SP6), Merz, R. (SP3), Blöschl, G. (SP6), Basso, S., Bertola, M. (SP6), Miniussi, A., Radovec, O., Samaniego, L., Thobar, S., Kumar, R. (2022): Shifts in flood generation processes exacerbate regional flood anomalies in Europe. https://doi.org/10.21203/rs.3.rs-2238190/v1

2) Software

Lun, D. (SP 6), Fischer, S. (SP1), Viglione, A. (Mercator-fellow). „corTESTsrd: Significance Testing of Rank Cross-Correlations under SRD“, R-package, https://CRAN.R-project.org/package=corTESTsrd.

Talks

1) Talks at conferences

Bertola, M. (SP6), Castellarin, A., Valtancoli, E., Viglione, A. (Meractor-fellow), and Blöschl, G. (SP6): Probabilistic regional envelope curves of floods in Europe, 12th International Workshop on Statistical Hydrology STAHY, Chia, Sardinia, Italy, 17-20 September 2022.

Fischer, S., and Schumann, A. (both SP1): Stochastic Generation of Type-specific Flood Hydrographs for Design Floods. 12th International Workshop on Statistical Hydrology STAHY, Chia, Italy, 17-20 September 2022.

Tarasova, L. (SP4), Lall, U.: The value of large-scale climatic indexes for forecasting the severity of widespread flooding using dilated convolutional neural networks, AGU Fall Meeting, December 2022, Chicago, USA

2) Poster

Mushtaq, S., Miniussi, A., Tarasova, L. (SP4), Merz, R. (SP4), Marra, F., Basso, S.: Modeling extreme floods emerging from heterogeneous processes by using the simplified Metastatistical Extreme Value Distribution. 12th International Workshop on Statistical Hydrology STAHY, Chia, Italy, 17-20 September 2022.

Theses

David Lun (SP6) (2022): Identifying changes and process controls of regional flood probabilities. PhD thesis defended on 28 June 2022, Vienna University of Technology, Austria.

Workshops, Conferences

AGU Fall Meeting 2022 Session: Hydrometeorologic Extremes: Prediction, Simulation, and Change. Conveners: Manuela Brunner, Laurie Huning, Larisa Tarasova (SP4) and Gabriele Villarini

Visits

Larisa Tarasova (SP4) visited Columbia University (USA) for two weeks in November 2022.

Matteo Pesce, a PhD student of A. Viglione (Mercator), has visited UFZ Halle (SP4) from July to October 2022 to work on identification and analysis of streamflow events in North-East Italy.