The Story of a Certain Project

When a certain Buddhist monk was once setting out on a long, difficult journey, he chose as his traveling companion a servant who was known for having a rebellious and quarrelsome nature. When asked why, he replied that he wanted to practice patience and humility. One might say that the three years when I headed the international CHIHE project were a similar lesson in virtues.

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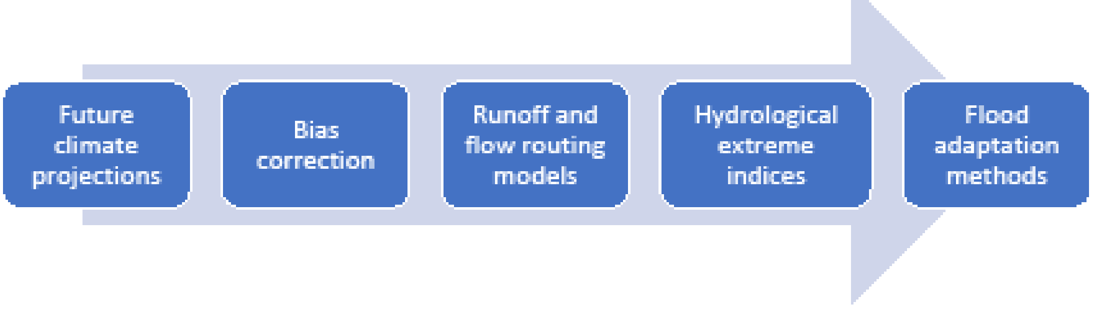
The *Climate Change Impact on Hydrological Extremes* project (CHIHE, http://chihe.igf.edu.pl/), funded by Norway Grants, was aimed at bolstering public awareness of the impact of climate change on extreme river flows (both high and low), and estimating their effects on the frequency and magnitude of floods and droughts. The project's research objectives, based on ten Polish and eight Norwegian twin catchments, included the following: statistical analysis of observed hydrometeorological time series, developing hydrological projections and estimating their level of uncertainty for the 1971–2100 time horizon, developing and applying methodologies for the analysis of flood and drought frequency in non-stationary conditions, making recommendations for strategies to adapt flood mitigation methods as part of the European Floods Directive, and creating a basis for researching the drought adaptation method.



Block diagram of the integrated knowledge base developed in the CHIHE project. It consists of a series of five linked modules. The first module is an information system tailored to the needs of working with large data sets (*Future climate projections*). The next module contains methods to correct simulation errors of meteorological variables derived from climate models (*Bias correction*). The *Runoff and flow routing models* module contains procedures for obtaining flow projections in the form of a simulation ensemble of hydrological and hydraulic models, including uncertainty analysis methods. The next module entitled *Hydrological extreme indices* includes methods of non-stationary flood frequency analysis, statistical analysis of environmental variable trends and flood risk estimation. Methods of adapting to floods under climate change are included in the last module.

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is a hydrologist and a member of the Hydrology and Hydrodynamics Department at the PAS Institute of Geophysics. She was head of an international project on the impact of climate change on extreme hydrological processes. Her work at the Institute of Geophysics (since 2007), and previously at Lancaster University, is devoted to mathematical modeling of hydrological systems with particular emphasis on identifying the models and uncertainties of prediction.

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Institutions and scientists taking part in the project

The project involved a total of 12 people, including four Norwegians. The Polish scientists, other than myself, included: Professors Witold Strupczewski and Jarosław Napiórkowski, Dr. Ewa Bogdanowicz, and Dr. Marzena Osuch. The Norwegian team was made up of: Dr. Hege Hisdal, Dr. Deborah Lawrence, Dr. Donna Wilson and Dr. Wong Wai Kwok. The project also involved doctoral students chosen in a competition among the global scientific community from over 100 participants. The competition winners included one student from Poland and two from Ethiopia. They were Joanna Doroszkiewicz, Hadush Kidane Meresa and Sisay Eshetu Debele. The teams worked on four parallel but also interdependent research tasks. Two of the tasks were led by Polish scientists, while the other two were managed by Norwegians. What was special about the project was the close collaboration between Polish and Norwegian scientific institutions, the PAS Institute of Geophysics and the Norwegian Energy and Water Resources Directorate (NVE). It should be stressed that Norway is more advanced in its work on the impact of climate change on the environment, especially with regards to existing studies and applications in practice. Our Institute undoubtedly contributed to the high level of scientific work conducted. However, the work was divided equally, which means that Polish scientists now have full know-how on researching the impact of climate change on environmental conditions. This allows us to conduct independent studies in this field on the highest global level. This was already apparent while working on the project. The research methodology developed in the project was used to analyze the impact of climate change in Africa, in the Nile basin, and in the polar circles at Spitsbergen.

The topics of doctoral dissertations best illustrate the justification and results of the studies conducted. They include setting trends for climate and hydrological change projections, the uncertainty of the results obtained, studying the methodology of analyzing the frequency of droughts and floods in non-stationary conditions (i.e., changing over time), as well as developing a methodology for adapting to future flood phenomena while taking into account climate change.

At the end of the project, a scientific conference was held to present the results of the project and discuss the guidelines and strategies for adapting to climate change in relation to floods. A conference entitled *Adapting to Climate Change: From Theory to Practice* was held on 5 December 2016 at the Staszic Palace in Warsaw. Its main objective was to help fashion guidelines for future adaptation measures of end-users, the representatives of regional and local authorities who will actively participate in the process of adapting to climate change. The discussion specifically focused on the need to educate the communities living in areas with an increased risk of flooding, both in terms of the existing risks, as well as methods of reducing them (such as by changing the structure of buildings and through spatial planning).

The main accomplishment of the project involved creating the first and only integrated knowledge base in Poland, including the development of methodology and tools for exploring the impact of climate change on the environment and society. The project also helped estimate potential changes to the drought index in future climate conditions in Poland and Norway. This, in turn, facilitates substantive discussions on how to adapt to climate change in relevant sectors of the economy (e.g. agriculture, forestry, water and energy management). One of the more important outcomes of the project was the launch of a catchment database for long-term research on the impact of climate change on hydrological conditions. The base consists of ten nearly natural catchments from different regions of Poland, where human activity is relatively limited. In addition, the acquired knowledge on modeling extreme processes in relation to the variable water regimes in Poland and Norway will be useful for various aspects of water management in both countries, as well as internationally. One such aspect is the ongoing research on the variability of thermodynamic conditions in the Arctic (West Spitsbergen) undertaken by Dr. Marzena Osuch. Another positive outcome is the collaboration with scientists from two other Polish-Norwegian projects, PolCitClim (http://polcitclim.uw.edu.pl/) and CHASE (http://www.chase-pl.pl/).

In contrast to other projects of this type, in addition to the 30-year time series reflecting the near future (2021–2050) and more distant (2071–2100), the 130-year time series of hydrometeorological projections (1971–2100) were used to determine the direction of the index changes, namely the frequency and magnitude of floods and droughts. Our research indicates that testing the variability of these indexes over a short period of 20–30-years results in highly uncertain estimates that are often not justified by long-term trends.

Our readers may find it interesting that in our research we use the term "projection" rather than "prediction." This means that the research results may indicate a greater or lower risk of flooding or droughts in the future, but not the specific years in which they occur. This is due to the fact that such detailed knowledge is not available, the results are highly uncertain, and atmospheric phenomena occur randomly. The most interesting discovery of the project involves being able to confirm the spatial variability of climate change. The farther north, the faster the air temperature is increasing. In 2100 it is expected that the temperature in northern Norway will increase much more than in Poland. Moreover, in catchments with snowmelt flood regimes, the flood flows may decrease while the average flow increases. The seasons are also changing. Decreased snowfall causes changes in the flood regime, but temporal variability of flood generating processes was not found in all the studied catchments. First of all, we must remember that the obtained projections are highly uncertain. The hydrological models used are based on data from measurements taken in a daily cycle, whereas in small catchments the flood duration should be measured in hours. Most importantly, the models used did not take into account potential sudden changes in environmental conditions that can completely change the nature of the catchment response to meteorological phenomena.

The impact of climate change on the amount of water, both droughts and floods, can have enormous economic, social and environmental consequences. Hydrological extremes have a direct impact on water-dependent sectors, including agriculture, forestry, fisheries, white (water) energy, water supply for humans and tourism. So it is very important to understand the occurrence and course of extreme hydrological phenomena in a changing climate. This will allow for the efficient management of water resources in changing environmental conditions. It means that all environmental plans for the future must take into account aspects of adapting to the future, potentially very variable, climate conditions.

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Further reading:

Debele SE, Bogdanowicz E, Strupczewski WG (2017a) A comparison of three approaches to non-stationary Flood Frequency Analysis. *Acta Geophys*. doi:10.1007/s11600–017–0071–4

Debele SE, Bogdanowicz E, Strupczewski WG (2017b) Around and about an application of the GAMLSS package to non-stationary flood frequency analysis. *Acta Geophys*. doi:10.1007/s11600- 017–0072–3

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Romanowicz RJ, Bogdanowicz E, Debele SE, Doroszkiewicz J, Hisdal H, Lawrence D, Meresa HK, Napiórkowski JJ, Osuch M, Strupczewski WG †, Wilson D, Wong WK (2016) Climate Change Impact on Hydrological Extremes: Preliminary Results from the Polish-Norwegian Project. *Acta Geophys*. 64 (2): 477–509. doi:10.1515/ acgeo-2016-0009.