IMPREX INNOVATIONS, TOOLS AND FUTURE DEVELOPMENTS

The development of adequate climate services for the water sector requires an effective combination of a robust scientific base and a client-oriented focus on the development of innovative and tailor-made tools and approaches.

INNOVATIVE TOOLS AND APPROACHES

- *Inclusion of compound events in risk analysis*
- *Crop yields and flood impacts derived from large scale climate indices*
- *Improvements to the drought risk management toolkit AQUATOOL*
- *Mapping impacts of remote climate extremes on food and manufacturing chains*

INCLUSION OF COMPOUND EVENTS IN RISK ANALYSIS

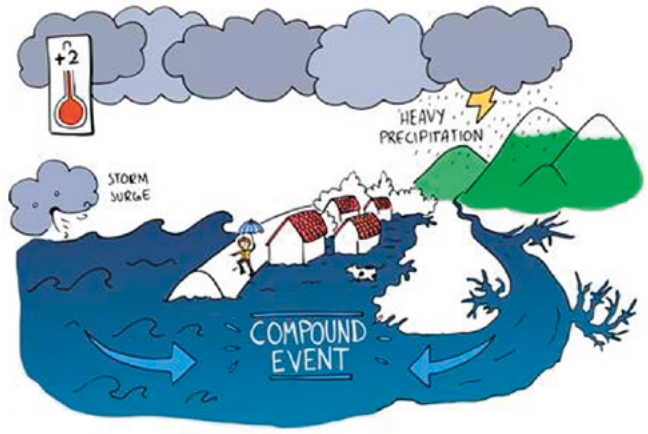


Figure 1: The emergence of compound events.

The scientific analysis of the impact of compound drivers of hazards or impacts has made substantial progress over the past years. The need to consider compound events has been documented in an IMPREX policy brief for European Flood Risk management, and flagged by authoritative publications by IPCC. With help from IMPREX a new European COST action DAMOCLES has been launched to promote awareness and systematic analysis.

In IMPREX work has been carried out including the development of new model data sets and analysis concepts, targeted at studying its relevance for flood risk management in a number of smaller Dutch catchment areas and municipalities. For instance, the city Den Bosch faces risks of flooding by a combination of high water levels in the river Meuse, and high local precipitation with associated flooding from smaller tributaries. Joint occurrence of these events is currently estimated by a rule-of-thumb approach, and this likely leads to a conservative estimate and overprotection of the area. HKV has used IMPREX resources to address this topic in a commercial contract with the city stakeholders, and explored the realism of these assumptions using additional techniques and regional climate model data.

The notion of compound events is well appreciated by many stakeholders involved in IMPREX, and is a component of the commercial portfolio of consultancy firms like HKV. However, the procedure applied for Den Bosch was conceived as too labor-intensive and requires further simplification and operationalization. In order to be absorbed in the stakeholders' decision processes, the advantages of this method need to be clear and convincing. Pilot studies conducted within IMPREX contribute to the identification and demonstration of these advantages. Usage of this method in day-to-day work of companies like HKV will further increase the awareness of this method among stakeholders.

CROP YIELDS AND FLOOD IMPACTS DERIVED FROM LARGE SCALE CLIMATE INDICES

Probabilities of occurrence of high-impact extremes (such as large scale flooding or crop yield failures) are linked to governing large scale climatic patterns. For instance, the North Atlantic Oscillation (NAO) is a pattern governing the large scale Westerly flow and is indicative for anomalously wet or dry conditions in specific European domains and seasons. Advanced machine learning techniques have been used to relate a number of influential climate patterns (e.g. NAO, El Nino and Eastern Atlantic pattern) to the occurrence of both, floods and crop yield anomalies in different European subdomains. The techniques are designed to extract information from past observations that could be used to make a forecast of the probability of major future impacts encompassing a time range of a few months. It was shown for instance that flood occurrence and damage in Southern and Eastern Europe are significantly related to winter and summer NAO. Also prediction of anomalies in sugar beet production can be made, for some regions, up to six months before the start of harvesting season. In these regions approximately 44% of the mean annual sugar beet is produced. This work was carried out in partnership with the European Joint Research Centre.

Some of these results are used in the IMPREX risk outlook, displaying an assessment of risks for hydrological impacts at a lead time of a couple of months, derived from multiple lines of evidence. In a follow-up study carried out by IVM, the method is being extended by including bottom-up local knowledge, which implies an active use of stakeholder information and people's perceptions of risk. The work shifts the focus from forecasting hazards towards impacts, which is a promising approach to generate meaningful outlooks and early warnings for targeted stakeholders.

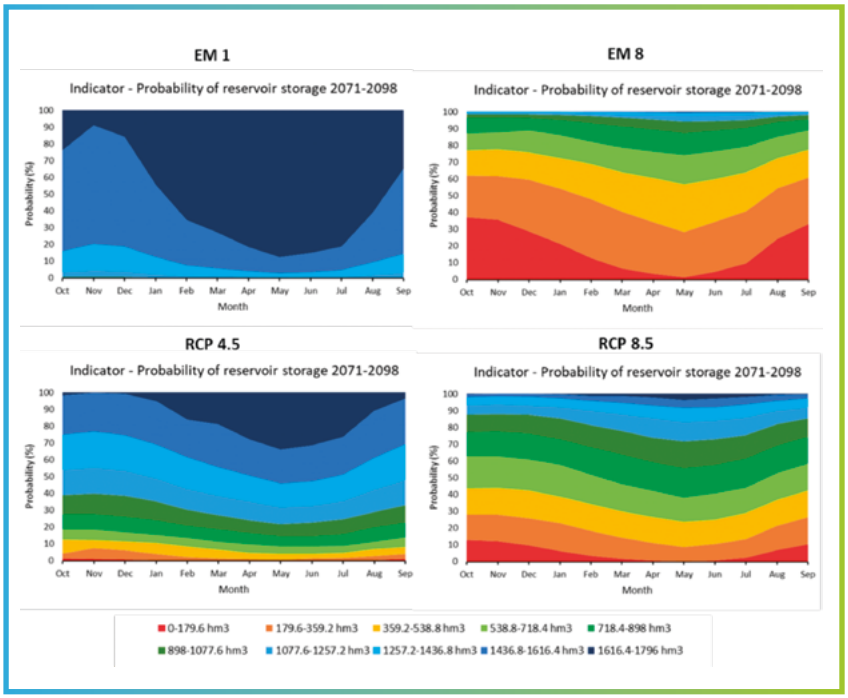
IMPROVEMENTS TO THE DROUGHT RISK MANAGEMENT TOOLKIT AQUATOOL

Within IMPREX, tools, models and approaches are improved that support decision making for both operational drought management (including water allocation) and long-term risk planning. The drought management procedures and organizations in the Spanish Júcar area (organized around the Júcar River Basin Partnership, CHJ) have a long standing tradition. Over the past decades a sophisticated Decision Support System has been developed, and the components dedicated to the data processing and quantitative modelling are embedded in a series of modules in the Aquatool decision support system.

Figure 2. Drought scenario by exploitation system in the Júcar River Basin District. Modified from the Monitoring of Drought Indicators Report in the area of the CHJ (May, 2018).

In IMPREX various incremental improvements have been implemented in some of these modules. First, an evaluation of the seasonal predictability of droughts in precipitation and streamflow forecasts has been carried out in the hydrological risk module of Aquatool. Then, the seasonal forecasts are incorporated in the hydrological risk assessment module of Aquatool (SIMRISK). The performance of this forecast product shows that bias corrections need to be applied, but small improvements are achieved in predicting the onset of the dry season compared to the operational procedure that is based on statistical modelling using observed precipitation records. By the main stakeholders this work is perceived as a first step towards inclusion of seasonal forecasting in the drought management support system. The tailor-made delivery of the probabilistic information for the target region was well understood and appreciated.

A range of climate change projections for the Jucar area have been evaluated, using the same decision support tool as used for operational and strategic drought management. Here a series of processing steps was carried out to adjust for biases and transfer ensemble climate projections to estimate water storage in a number of reservoirs in the area, and consequently drought risk in the catchment. Apart from considerable unforced internal variability, a clear difference in drought risk was displayed for different climate change scenarios.



The developments of AQUATOOL are rooted in a long history of decision support system development for the Júcar area. However, the system can be implemented in any Spanish basin (and other basins abroad) where the model chain and AQUATOOL calibrated modules are available. The tailoring of both seasonal forecast and climate projection results to the local decision support system, AQUATOOL, has strongly contributed to the refinement and greater acceptance among local stakeholders, although more research is needed in order to further improve the skill of the predictions.

Figure 3. Probability indicator of reservoir storage for future period 2071-2098 in the Jucar River System from two ensemble members (EM1 and EM8, top left and top right respectively) and the ensemble of RCPs 4.5 (bottom left) and 8.5 (bottom right).

MAPPING IMPACTS OF REMOTE CLIMATE EXTREMES ON FOOD AND MANUFACTURING CHAINS

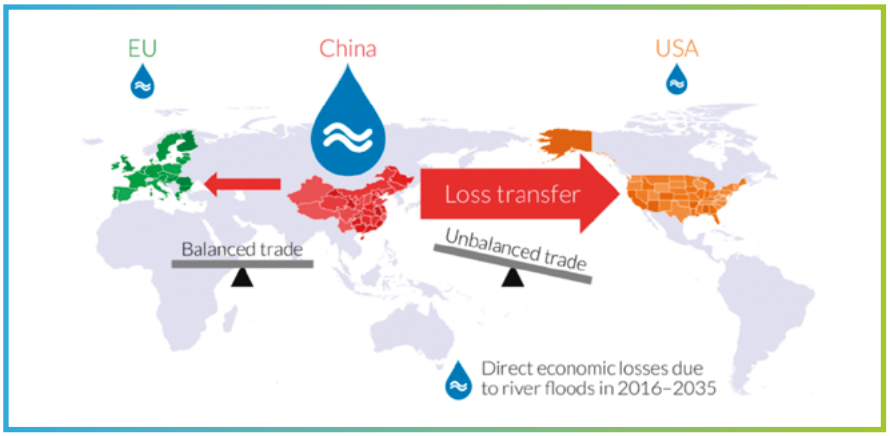


Figure 4. Economic response to global river floods. Whereas the USA suffer from indirect losses due to river floods in China, the European Union is much better prepared. This can be derived back to a balanced trade relationship between the EU and China in contrast to an unbalanced trade between China and the USA.

An extensive analysis is made of water consumption and trade networks of a large collection of crops used for food production. Linking the trade and production chains with ambient climate features, a climate risk profile for each of these crops was produced. Using a trade network model (Acclimate) the global web of trade and manufacturing processes has been mapped and analyzed for impacts of flood related shocks in the system. The mapping uses a discretization into regions and sectors and is assumed to cover a majority of the total worldwide economic production. The system is driven by national/regional economic statistics, and allows mapping global trade balances between regions and the effects of cascading effects of climatic shocks on those trade balances.

In the globalizing world trade shocks induced by floods in production areas depend strongly on the trade network. Increased trade connectivity allows faster propagation of shocks through the trade network, but also allows effective mitigation by choosing alternative supply channels. In general a strong connectivity in combination with a balanced trade relation limits propagation of adverse flood effects to partner regions and improves mitigation options.

These analyses can inform international food production or retail companies about the current and potential future vulnerability of their supply chains. This enables the development of coping strategies to reduce risk risks (i.e. through targeted portfolio diversification), or forecast-based action in the face of impeding disasters.

Results are published in high-profile academic journals and at press conferences, and are being included in follow-up research programs under the Horizon 2020 funding scheme. In addition, pre-startup funding was received to turn the results in (commercial) services for public and private institutions. The services include standardized risk assessments for reporting or stress testing companies or sectors, development of authoritative and tailor-made risk scenarios, and potentially the implementation of an early warning system fed by operational (seasonal) hydrometeorological forecasts.

Examples of other concepts and tools (documented elsewhere)

- *Probabilistic damage modelling using open data* (see factsheet on Flood Risk and policy brief on European Flood Directive): the developments allow a pan-European derivation of flood damage as function of the flooded area and exposed assets. It enters the portfolio of research and consultancy projects from agencies like Deltares.
- *Forecasting water level for ship traffic management in Central European rivers including Rhine* (see factsheet on Water Transportation): a prototype forecasting system is implemented and heavily utilized by a large group of clients; follow-up funding is provided to operationalize the forecasting system.
- *Risk based water allocation under dry conditions* (see factsheet on drought management): An updated drought risk analysis and management system is ready to be implemented for the Netherlands. It will generate important lessons on stakeholder involvement and information usage applicable to other regions in Europe.
- *Assessment of the economic value of forecasts for hydropower* (see factsheet on hydropower): the uniform procedure to evaluate forecast impacts on hydropower production value has led to changes in hydropower operation. A follow-up investment from a Regional Hydropower Agency is used to make the system developed in IMPREX operational.
- *A system dynamics model for mapping multidisciplinary interactions and trade-offs in water allocation problems* (see factsheet on drought management)
- *Mapping drought risk through an objective index definition tool FRIDA* (see factsheet on drought management): FRIDA allows a realistic tailor-made identification of the current drought state, and gives information on the impact of measures to alleviate drought risk. It increases consistence of information necessary for operational and strategic decision taking.
- *Forecasting high turbidity events in Drinking Water Treatment Plants* (see factsheet on Drinking Water supply): using observed and forecasted local rainfall, a forecast of turbidity is made allowing better management and cost savings of treatment operations. Via the CetAqua shareholder SUEZ the forecasting system will be adopted and distributed over a larger number of Drinking Water Treatment Plants.
- *Water Accounting + mapping climate change features* (see factsheet on drought management): a standardization of the "book-keeping" of water availability and consumption allows comparison and upscaling of catchment based water accounts to the European scale. At this aggregation level climate change information becomes meaningful for European Drought Management strategies.

For further information please visit www.imprex.eu and check out our interactive product demonstrator!

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IMPREX is designed to help reduce Europe's vulnerability to hydrological extremes by achieving a better understanding of the intensity and frequency of potential disrupting events. Enhancing our forecasting capability will increase the resilience of European society as a whole, while reducing costs for strategic sectors and regions at the same time. The research project brings together 23 partners from 9 countries and has received funding from the European Union's Horizon 2020 Research and Innovation Programme.