Facility for global assessment of hydrological effects of climate change

Applicants:
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Discipline: Hydrology – Global forecasting
Kerndomein: 9.2
Business units: Deltares-Zoetwater systemen; Deltares- Ondergrondse systemen

Scientific background

Climate change affects many different sectors, e.g. flood protection, agriculture, housing, industry; and themes, e.g. water management, spatial planning, economy (REF, EEA). Which sector or theme is mostly affected varies from region to region. However, the hydrological response, i.e. the change in flood and drought frequency and the water management required, is considered a key effect everywhere (REF, IPCC, EEA). Many economical sectors are affected indirectly by climate change through changes in the hydrological system. Strategies for water management are needed to mitigate the most undesired effects of a changing climate or to gain from the positive effects. Research to the impact of climate change forms the scientific basis for the design of adaptation strategies. To design efficient water management strategies these scientific key issues need to be addressed:

1. *the extent to which the future variation in water supply will differ from the current variation;*
2. *the ratio between the trend and the noise in the future water supply;*

Climate scenarios and their hydrological response are used to address these issues. The climate scenarios are provided by global climate models (Ocean-Atmospheric Ocean General Circulation Models, AOGCMs). AOGCMs are 3 dimensional models that can simulate the global climate for different trends in greenhouse gas emissions. The resulting climate at the earth surface is provided on a resolution of 2-3 degrees long/lat. The models differ not only in their skill to represent the current climatic conditions but also in their predictions for precipitation changes in many regions in the world. As for the climate, the hydrological response is simulated using numerical (hydrological) models and different models will show different responses on the same climate forcing. Moreover, the skill of different hydrological models varies strongly from region to region (REF???)

This last consideration provides the third key issue to address:

3. *The skill of the combinations of climate and hydrological models on a global scale in representing the current hydrological conditions.*

Multi-model comparison is the approach required to gain information on the key issues (REF, IPCC scenario manual). So far very few attempts have been made to provide hydrological multi-model comparisons, particularly on a global scale. This is understandable as the preparation of a system/model that is able to do this, is normally beyond the time frame of

any individual research project. Although the results of climate modelling experiments are available through internet, i.e. the IPCC data distribution centre, preparation of this data for further use needs substantial data handling which is far from easy due to the data volume, the differences per model in formats, parameters, temporal and spatial resolution.

In practice this means that most studies that assess the impact of climate change to water resources limit their analysis to a few climate scenarios and a single hydrological response model. Both from a scientific as from a management point of view this is undesirable as the choice of the climate scenario and hydrological model strongly determines the result.

Research objectives

1. ***to develop a system that is suited to handle output data from all AOGCMs available at the IPCC data distribution centre and translate this into a hydrological response on a global scale.***
2. ***to evaluate the global hydrological response according to different combinations of climate model results and hydrological models on:***
   a) the comparison of the skill of different models in simulating the hydrological response in different regions in the world.
   b) The predicted change in the variation of hydrological parameters in different regions in the world and
   c) the ratio between trend and noise in hydrological parameters due to climatic change in different regions in the world.
3. ***To evaluate the scenario results on their meaning for water resources management***
4. ***To develop an internet facility that allows third parties to download the results in form of digital raster maps maps which can be used for further research purposes.***

To make freely available software that can be used to combine these data with user-developed hydrological models.

Available utilities

At the start of the project we can utilize a number of tools, data and models gathered and developed by the research group over the last years. For the feasibility of the project this accessibility is considered essential. The key components ready for use are:

- For the development of the technology we will make use of the DELFT-FEWS software. This software is currently applied in operational flow forecasting in many regions of the world. The software
  - can handle near real time vast volumes of meteorological forecasted and real time data and products currently available such as weather predictions as well as ensemble weather predictions from different numerical weather models; rainfall radar data; remotely sensed data as well as on-line measured hydrological and meteorological data.
  - allows for the application of various hydrological models or prediction methods;
  - is developed in Java and platform independent where exchange of information between the components is done through a Published (XML) Interface

  - the system can be used both as stand alone as well as client-server system, which is particularly important for multi-user systems when the data bases needed to make the forecasts are centrally managed.

- During the last three years a distributed model has been developed at the Utrecht University specifically for global applications. An uncalibrated model version is currently running under the DELFT-FEWS environment. In addition hydrological model codes of the Sacremento model, HBV model, Xiangang Yang have been re-written in the PCRaster modelling language (R&D distributed modeling and FEWS) and can be applied as spatially distributed versions of these soil moisture accounting models. These models can be easily brought under the DELFT-FEWS environment.
- For the development of this model global data sets have been collected and prepared for rainfall (ERA40 and CRU), Evaporation, temperature (all on daily basis), soil moisture (REF) groundwater (REF); geology; river discharges
- Remotely sensed assessments are available of soil moisture on a daily basis with 25km spatial resolution, based on the AMSR-E sensor
- Results from AOGCMs can be gathered from the IPCC data distribution centre The number of available experiments is growing. At the time of writing the number of climate models was 24 each of which at least 3 experiments were available experiments available.

Research approach

The research approach is straight foreward.

Develop a system that is suited to handle output data from all AOGCMs available at the IPCC data distribution centre and translate this into a hydrological response on a global scale.

The results of the AOGCMs are made available by the climate research institutes through the IPCC data distribution centre and can be downloaded freely from the internet (REF WEB-SITE). Handling these data, however, is far from easy due to the data volume, the differences per model in formats, parameters, temporal and spatial resolution. Also impact studies are carried out on typically higher resolution than provided by the climate models, which means that the climate parameters need to be transferred to the desired resolution. The result is that each impact study has to invest considerable time in data handling to prepare their input data. This situation is undesired as it means that less time is available for analysis. Based on existing software (DELFT-FEWS) originally developed for the purpose of flood forecasting, we will develop a this system. The purpose is that we will configure the DELFT-FEWS software such that it enables to:

- Import the necessary data sets from the IPCC data distribution centre
- Import the climatic and hydrological reference data
- Convert the data to a geographical reference system
- Visualize the climate data of both observations and model simulations
- Check the data for errors
- Make basic comparisons between observed and simulated data in space and time
- Interpolate data to a required temporal and spatial resolution
- Run the different hydrological model codes
- Collect the local time series results of the models for reference stations as well as the results in form of maps
- Visualize the hydrological model results

- Allow for evaluation of multi-model performance both in space and time
- Archive the model results including meta data in a data base
- Export the results to a prescribed format for further analysis in using other software

When ready the system will allow for evaluating the hydrological response using different hydrological model codes using different climate input. The resolution on which the results are provided will be 0.5 degrees lon/lat. This is higher than the resolution used by climate models and sufficient for resolution for large river basins regional hydrological assessments. Although higher resolution can be considered, we choose for a system that can run on currently available PCs to allow third parties to work with the system. The system will be made sufficiently flexible to increase the resolution when computer power and available climate data sets allow for more detail. The system will be developed such that it is platform independent.

Evaluate the global hydrological response according to different combinations of climate model results and hydrological models

A substantial part of the research will be the comparison of *the skill of different models in simulating the hydrological response in different regions in the world*. To compare the different models we we will evaluate a limited number of hydrological modelling codes. These will be calibrated and validated using global data sets on historical precipitation and discharge using split samples for different river basins. In particular we would test skills in terms of ability to simulate the correct occurrences and localities of extremes and their ability to produce the correct spatial and temporal signals. For this we propose the application of a series of performance indicators to evaluate the model skill of the different models and analyse the results to determine the main error sources. Model skill will be measured both in time as in space. Here use of remote sensing maps for validation purposes under current conditions will play an important role. We propose to use space based soil moisture assessments provided by the AMSR-E sensor on the AQUA satellite; and space based assessments of global snow extent using MODIS.

The predicted change in the variation of hydrological parameters in different regions in the world will be evaluated by running the different hydrological model codes using input of the results from different climate model experiments. These experiments typically start late 19th century or early 1900 to include the pre-industrial climate conditions and run until 2100.

The simulations will result in

- an ensemble of hydrological responses in many basins in the world representing the hydrological conditions during the last century according to the climate/hydrological model combinations and;
- an ensemble of scenarios of hydrological responses for many river basins in the world on future climate change in terms of discharge and other hydrological parameters.

Running the different hydrological model codes using the results of the AOGCMs for the present day conditions will shed light on the quality of different climate models for simulating the present day hydrology.

Running the different hydrological models using the scenario runs of different AOGCMs. will provide an ensemble of global hydrological future scenarios according to different combinations of climate scenarios and hydrological models. The ensemble series on future

hydrological conditions will be analysed *on the change in variation of the parameters both in time and space.* We will analyse *on a global scale if and where the expected trends will be dectectable from the present day noise in the hydrological parameters*. The produced series allow for both comparisons between model outcomes as well as comparisons between model outcome and observed series.

To evaluate the scenario results on their meaning for water resources management and other uses

The following is proposed:

- Evaluate the hydrological scenarios in terms of changes in occurrences of floods and droughts. This will provide essential information to be applied in water management adaptation studies.
- Evaluate the model results in terms of fresh water input in the Northern Ice Sea. Assessment for these fresh water volumes is important for climate change studies.
- Evaluate the model results in terms of fresh water availability, now and in future, for water management demands.

The results will be compared with the currently available hydrological assessments on a global scale as provided by models such as WaterGap the It is the purpose to organise a workshop on global model comparison near to completion date of the research.

To develop an internet facility that allows third parties to download the results in form of digital raster maps and time series which can be used for further research purposes.

Running this many model experiments will result into a vast volume of resulting data. The data will be in form of digital maps, representing temporal series on hydrological parameters as snow cover extent, soil moisture indices, annual and seasonal runoff, actual evaporation; as well as in form of time series for daily runoff at specific locations (e.g. the outflow point of large basins, points where the basins enter the sea/ocean etc. We will prepare a web based facility that allows for third parties to download the hydrological model results (time series of maps and local reference points) for further use and visualize the results.

This should result in a facility comparable with the data distribution centre of the IPCC for global hydrological effects of climatic change. It will allow third parties to freely use the results for further analysis or application in water management or climate adaptation studies and projects anywhere in the world. This facility will be operated by the Dutch DELTARES institute for the coming years

To make freely available software that can be used to combine these data with user-developed hydrological models

- Making the results and the software available for third parties may be by different means:
- a client-server application, where the software runs on a central server and only data is exchanged.
- By a scenario inspector, where users can visualize the scenario results and download the results.
- By downloading the software Alternatively the software can be downloaded by users to run it.

Deliverables

a) a system that is suited to handle output data from all AOGCMs available at the IPCC data distribution centre and translate this into a hydrological response on a global scale.
b) Digital maps that show the predicted change in the variation of hydrological parameters in different regions in the world
c) A facility that allows third parties to use the results for further evaluation
d) PhD thesis
e) Papers in the scientific literature
f) Workshop on model comparison

Relevance for science, technology or society

The results allow for comparison the hydrological response of various climate scenario's on a global scale and make available the results for the global climate and water research and consulting community. So far such hydrological facilities are not yet available. The research is directly relevant for populations threatened by climate related hydrological changes. The results can particularly be used in data poor river basins, which can be very beneficial for projects that aim at climate impact assessment. We foresee that many of these projects will be carried out in the coming years.

Relevance for Deltares

As the goal is that the results should be made easy accessible for all users, and the tools need to be further developed for practical applications DELTARES is a technological institute that makes available scientific knowledge on water for practical purposes. The benefit for DELTARES is that it is an interesting development as the availability of this information can substantially ease the execution of international water related projects. DELTARES is able to to maintain the results by operating the resulting data base in future and has the infrastructure, to maintain the facility in the coming years. This ensures that the results find their way for utilisation outside the scientific world. Supplying this information puts Deltares internationally in the centre of the water related climate research studies.

Planning

	Yr 1	
		Milestone
	days	
Technical development		
Learning Delft Fews	20	
Development Import facility	10	Climate data can be imported and visualized
Development of additional interpolation routines	30	Climate data can be interpolated to the required resolution
Development of an automatic calibration tool	100	Calibration tool in FEWS
Development of comparison tools	40	Comparison tool in FEWS
	200	
Research		
review	40	
Learning software	20	candidate can configure Delft FEWS
Develop data base	30	Data base ready
Implementation of Global model in Delft FEWS	10	Working system
	100	

	Yr 2	
		Milestone
Technical development	days	
Create Data base link	50	Data base linked to FEWS
Development performance indicators	40	Performance indicators in Delft FEWS
Developement of comparison tools RS data	70	Comparison for
Set up Archiving system	40	Archiving system ready
	200	
Research		
Implementation Global model (s) in FEWS		
Analysis climate data	40	Memo
Calibration basins	90	
Reporting model quality	30	Report on model quality
Comparison RS data	20	
Review	20	Chapter Literature review
	200	

	Yr 3	Milestone
Technical development	days	
Develop web based facility	100	Web based facility ready
Testing components for operational use	100	
	200	
Research		
Comparison RS data	50	Chapter validation
Run IPCC scenarios	75	
Analyse results	75	Memo
	200	

	Yr 4	Milestone
Technical development	days	
Completion of software for distribution	100	
Testing components for operational use	100	System ready for use
	200	
Research		
carry out specifc studies (2)	100	
Reporting	100	Chapters on specific studies
	200	

	Yr 5	Milestone
Technical development	days	

Organisation

In proposal we assume a PhD at the University Utrecht to be supported by Deltares Staff

Finances

	2008	2009	2010	2011	Totals
PhD	40	42	44	46	172
Marc Bierkens (TNO-B&O)	10	10	10	10	40
Jaap Kwadijk (WL-ZWS)	10	10	10	10	40
Support FEWS-Team	15	20	15	5	55
Conference			pm	pm	
	75	82	79	71	307