PROJECTIONS OF SEDIMENT BUDGETING AND RIVER MORPHOLOGY FOR GERMAN WATERWAYS UNDER FUTURE CLIMATE CHANGE

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1. BACKGROUND

Sediment accumulation, as well as erosion may cause insufficient water depths or narrows in the navigation channel. Changes in the sediment supply, as well as in the hydrology (maximum flood levels, duration and frequency of floods, duration of low-flow periods etc.) potentially disturb the sediment budget of a river. In order to reach stable river bed conditions, a balanced sediment budget has to be achieved. Hence, to avoid negative impacts on the navigability, maintenance measures like sediment nourishment and dredging or alteration of river training structures can become necessary.

Recent research results [Krahe et al., 2009 ; Görgen et al., 2010] indicate a possible span of hydrological changes resulting from projected climate change in the catchments of German waterways (projections for the 21st century at the Rhine). The exact pattern and the degree of these changes are still subject of further studies. Here, we present the first results of sensitivity experiments using numerical simulations resulting from three different couplings of climate, hydrological and hydromorphodynamic impact models.

2. APPROACH

Within the scope of the KLIWAS research programme – initiated and financed by the Federal Ministry of Transport, Building and Urban Development (BMVBS) – a comprehensive analysis of potential impacts of climate change on German waterways is being carried out by several research institutions (www.kliwas.de). One goal is to assess potential impacts resulting mainly from rainfall and temperature changes on German waterways and navigation, as well as on changes of habitats and water quality. To this end, a chain of

models has been set up: global climate models are being regionalised and project the patterns of rainfall and temperature depending on global emission scenarios. The hydrologically relevant parameters are then projected on the river drainage basins, which leads to run-off scenarios [e.g. Krahe et al., 2009 ; Görgen et al., 2010]. Fig. 1 shows the input of basin-wide hydro- and morphodynamic models.

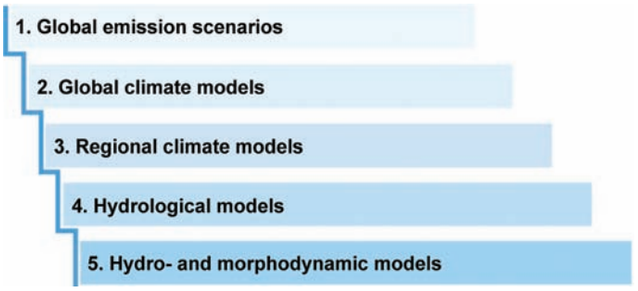

Fig. 1: Model chain applied in the KLIWAS-research programme

For the assessment of the impact of climate change on navigation, as well as on changes of habitats and water quality, the sediment budget is a key factor. It determines the trend of possible bed level changes as well as transport rates of bed-load and suspended material, turbidity and substrate grain diameters. Changes in the sediment budget can be derived from morphodynamic modelling of different scenarios which are referred to as projections in the following.

3. STATE OF THE PROJECT

The complexity of the research programme calls for the co-operation of research organisations with their particular expert knowledge. In the research task concerning the inland waterways, the involved partners are the Federal Institute of Hydrology (BfG) the National Meteorological Service (Deutscher Wetterdienst – DWD) and the Federal Waterways Engineering and Research Institute (BAW). Existing models have to be extended under the scope of climate projections until the year of 2100. Moreover, the exchange of data from one link of the model chain to the next has to be established.

Currently, the first sets of projections have passed the model chain with morphodynamic calculations running until 2050. Additional model chains including new emission scenarios from the next IPCC-report will be included when available. The procedures used in the model chain will be further improved. For instance, maintenance operations (sediment dredging, dumping and the bed-load nourishment) are currently accounted for in a rather arbitrarily simplified way: mean values of sediment extraction or addition are being calculated from past operations and continuously introduced for the future period as average values at each calculation grid point, which resample about 500 m of stream length. At a later stage, this simple method will be replaced by an algorithm, which simulates maintenance operations by automatically responding to changes in water depths. For these reasons, all morphodynamic projections made so far are preliminary with the main focus on sensitivity analysis and technology assessment.

In this article, two examples for analyses concerning the river morphology will be given. Firstly, in Fig. 2, the evolution of the mean bed level of the Rhine between the Iffezheim barrage (336 km) and Kaub (546 km) under three different climate projections is given. The chosen scenarios are exemplary and do not necessarily cover the full range of projections with respect to possible hydrologic change. They differ in the underlying emission scenarios, as well as the regionalisation method of the global climate model data. The projections are to be compared to a reference run, which simulates the development of the bed level under the continuous repetition of the hydraulic conditions of the period 1992-2004.

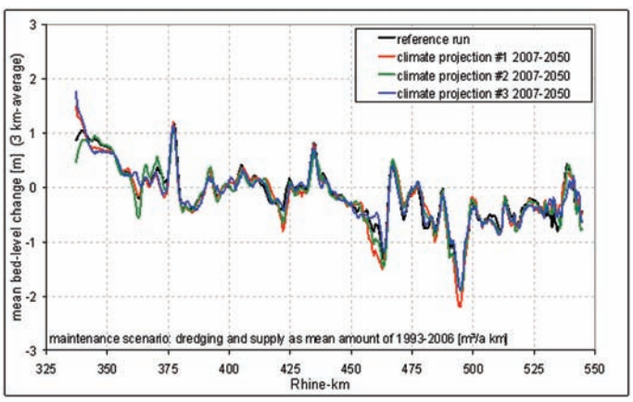

Fig. 2: Projected mean bed level change between 2007 and 2050 in metres for the Rhine resulting from three different preliminary climate projections compared to a reference run (hydraulic conditions of the period 1992-2004)

The development of the bed level is showing similar patterns for the three climate projections and the reference run. The extent of the changes, however, differs between the runs. As these results are still preliminary, no conclusions can be drawn for the necessity of measures so far. Maintenance operations are included in all simulations, but in a very simplified way, which does not represent the expectable reaction of the Waterways and Shipping Administration well enough.

The second example for an analysis regarding the future development of river morphology is given in Fig. 3. Here, the possible cross-section averaged water depth changes at different locations of the Rhine is given in meters per decade, averaged over the simulation period 2010-2050. Within the cross-section the averaging is done over the full width of the free flowing section, not only the navigation channel. The results are derived from three different climate projections and a reference run, which are the same as the ones underlying Fig. 2. It can be seen, that the projections predict certain future changes in water depths which are caused by bed level changes as well as changes in the hydrographs. As already mentioned, the preliminary status of the results prohibits conclusions with respect to actions to be drawn at present.

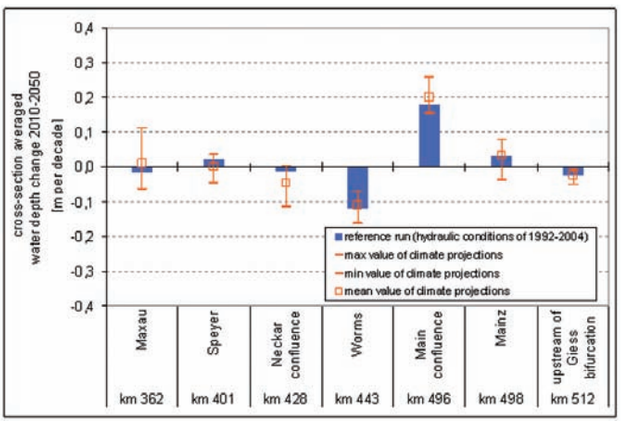

Fig. 3: Cross-section averaged water depth change (in metres per decade) for the Rhine between 2010 and 2050, resulting from three different preliminary climate projections compared to a reference run (hydraulic conditions of the period 1992-2004)

4. CONCLUSION

A chain of models is being set up in order to assess potential impacts on German waterways resulting from climate change. Changes in the sediment budget, resulting in bed- and water level, as well as grain diameter changes, are the key in the assessment of impacts on navigation, as well as ecology and water quality. In future steps, the effectiveness of possible adaptation measures can also be estimated by changing the model parameters accordingly.

At this project-stage the model chain is being set up and the data transfer scheme is under optimisation. All parts of the model chain are working and robust results can be expected by the end of the project in 2013. This analysis will provide a data base suitable to identify possible challenges and adaptation measures.

5. BIBLIOGRAPHY

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SUMMARY

Recent research results indicate impacts of climate change on hydrological conditions in German waterways (projections for the 21st century at the Rhine). Within the scope of the KLIWAS research programme – initiated and financed by the German Federal Ministry of Transport, Building and Urban Development (BMVBS) – a comprehensive analysis of potential impacts of climate change on German waterways is being carried out by several research institutions. One goal is to assess potential impacts resulting mainly from rainfall and temperature changes on German waterways and navigation, as well as on changes of habitats and water quality. To all these aspects, the sediment budget is a key factor, determining the trend of possible bed level and water level changes as well as grain size compositions.

A chain of models is being set up in order to fulfil the project goal: global climate models are being regionalised and project the patterns of rainfall and temperature depending on global emission scenarios. The hydrologically relevant parameters are then projected on the river drainage basins, which leads to run-off scenarios. These are the input of basin-wide hydraulic models which are coupled to sediment transport models. In this way, the impact of the global climate change on the sediment budget of the German waterways can be evaluated. In future steps, the effectiveness of possible adaptation measures can also be estimated by changing the model parameters accordingly.

At this project-stage the model chain is being set up and the data transfer scheme is under optimisation. All parts of the model chain are working and robust results can be expected by the end of the project in 2013.

RESUME

Les résultats scientifiques récents montrent la possibilité de l'influence des changements climatiques sur les conditions hydrologiques des voies fédérales navigables (projection 2071-2100 pour le Rhin).

Dans le cadre du programme de recherche scientifique allemand appelé KLIWAS (Klimawandel und Wasserstraßen = changement climatique et voies navigables fédérales) – commissionné et financé par le ministère fédéral allemand du trafic, de construction et du développement urbain – une analyse détaillée sur les conséquences possibles des changements climatiques sur la navigabilité est menée par différentes institutions de recherche scientifique. Un des buts est l'évaluation des conséquences possibles sur la navigabilité, ainsi que l'aptitude des habitats et la qualité d'eau des voies navigables fédérales, qui s'ensuit principalement des changements de précipitation et de température. Pour tous ces aspects, l'inventaire du sédiment représente un aspect clé, qui détermine la tendance des changements de hauteur du niveau de fond et du niveau d'eau ainsi que la composition granulométrique.

Pour obtenir le but du projet, une chaîne de modèles numériques a été réalisée: des modèles climatiques globaux vont être régionalisés et projeter un modèle de précipitation et de température en fonction de scénarios d'émissions globales. Ensuite, les paramètres hydrologiques pertinents seront projetés sur les bassins de drainage des fleuves par lesquelles ont obtiendra des scénarios d'écoulement. Ceci représente les données d'entrée pour les modèles de bassin de fleuve, qui sont liés à des modèles de transport du sédiment. De cette manière, les effets du changement climatique global sur les voies navigables fédérales peuvent être évalués. A l'avenir, l'efficacité des options d'ajustement peut être estimé par des changements de paramètres du modèle correspondant.

En ce moment, la chaine de modèles est complètement installée et le schéma d'échanges de données sera optimisé. Toutes les parties de la chaîne de modèles numériques seront utilisables et les résultats fiables seront attendus vers la fin du projet en 2013.

ZUSAMMENFASSUNG

Aktuelle Forschungsergebnisse zeigen einen möglichen Einfluss der Klimawandels auf die hydrologischen Bedingungen an den deutschen Bundeswasserstraßen (Projektionen für das 21. Jahrhundert für den Rhein). Im Rahmen des Forschungsprogramms KLIWAS – beauftragt und finanziert durch das Bundesministerium für Verkehr, Bau und Stadtentwicklung (BMVBS) – wird eine umfassende Analyse möglicher Auswirkungen von Klimaänderungen auf die Binnenwasserstraßen von verschiedenen Forschungsinstitutionen durchgeführt. Ein Ziel ist die Bewertung möglicher Auswirkungen auf die Schiffbarkeit sowie die Habitateignung und Wasserqualität der Bundeswasserstraßen, die hauptsächlich aus Niederschlags- und Temperaturänderungen resultieren. Für alle diese Aspekte stellt der Sedimenthaushalt eine Schlüsselgröße dar, welche den Trend möglicher Sohlhöhen- und Wasserspiegellagenänderungen sowie die Korngrößenzusammensetzungen bestimmt.

Um die Projektziele zu erreichen wurde eine Modellkette aufgebaut: Globale Klimamodelle werden regionalisiert und projizieren die Muster von Niederschlag und Temperatur in Abhängigkeit globaler Emissionsszenarien. Die hydrologisch relevanten Parameter werden dann auf die Flusseinzugsgebiete abgebildet wodurch Abflussszenarien erhalten werden. Diese stellen die Eingangsgrößen von hydraulischen Flussgebietsmodellen dar, welche an Sedimenttransportmodelle gekoppelt sind. Auf diese Weise können die Auswirkungen des globalen Klimawandels auf die Bundeswasserstraßen beurteilt werden. In weiteren Schritten kann die Wirksamkeit möglicher Anpassungsoptionen durch Änderung der entsprechenden Modellparameter ebenfalls abgeschätzt werden.

Zu diesem Zeitpunkt wird die Modellkette vollständig installiert und der Datenaustauschprozess wird optimiert. Alle Teile der Modellkette sind funktionstüchtig und belastbare Resultate sind gegen Ende des Projekts im Jahr 2013 zu erwarten.