人新世におけるグローバルな社会水文学
Socio-Hydrology on the global scale in the Anthropocene

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There are several motivations and rationales why socio-hydrology is emerging. Even though the responses of water on the earth to human activity are those the discipline of hydrology covers as UNESCO defined in 1964, hydrologists mainly pursued to observe and understand water cycles on the earth from natural scientific point of view. Typically, "naturalized flow" was estimated and simulated even for practical prediction of stream flow into reservoirs.
In the 21st century, the recognition of the Anthropocene prevailed that "real" environment is modified by human influences and differs substantially from "natural" environment, mainly because the changes and the impacts of climate due to the increase of greenhouse gas emissions by human beings became apparent. Real land use and land cover, instead of potential or natural land cover and land use, should be given as boundary conditions for realistic simulation of climate system, and plausible future predictions of land use and land cover including the changes of vegetation should be given for reliable predictions of future climate.
It was not apparent whether human activities, such as reservoir operations and water withdrawals for human needs, have significant impacts on the global hydrological cycles and feedbacks for climate systems, realistic consideration of human interventions have been required for realistic estimates of the impacts of climate change.
These have been the major drivers to promote socio-hydrology on the global scale, and the human interventions on water cycle, such as reservoir operations and human water withdrawals from rivers and ground water, have been included in hydrological and water resources modeling. Owing to the development of socio-hydrologic modeling on the global scale, it was prevailed, for example, storing water in man-made reservoirs should have been suppressing the sea level rise with comparative rate with other causes such as glacier melt in Greenland and Antarctica, ground water in several regions in the world has been depleting substantially and pushing up the mean sea level as a result of mass balance of water in the hydrosphere, and the impacts of climate change on the water resources management would be less significant with autonomous adaptation by changing crop calendar and reservoir operations.
Such a socio-hydrologic development in global hydrology is promising to promote scientifically relevant, socially expected, and personally dedicated studies. In the 20th century, hydrological science was expected to be objective and value-neutral, however, in the Anthropocene in the 21st century, it is expected to propose possible alternative options how to respond to natural and anthropogenic changes in hydrologic cycles even on the global scale. Overview on the socio-hydrologic modeling on the global scale will be presented.

キーワード：人間活動、水循環、水資源
Keywords: human interventions, hydrological cycle, water resources

Modeling the river discharge responses to climate variation and vegetation change in the Loess Plateau

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Simulation of the mutual interaction between hydrological processes and vegetation dynamics is important for understanding and predicting regional hydrological change caused by the climate variability and local land use/cover change. Traditional hydrological models simulate the impact of vegetation change using a simple parameterization scheme. Land surface models emphasize the vertical transfer of energy, water and carbon dioxide in the soil-vegetation-atmosphere continuum, however, some important hydrological processes are over simplified in these models. To fill these gaps, this study chose the Community Land Model version 4 (CLM4) and the Geomorphology Based Hydrological Model version 2 (GBHM2), and replaced the runoff generation and flow routing schemes of CLM4 by the schemes used in GBHM2. The new eco-hydrological model was developed in a study basin with semi-arid climate, the Wudinghe River basin (WRB), which located in the middle reach of the Yellow River with a drainage area of 28706 km^2. After a comprehensive calibration and validation, the model was applied for simulation of the eco-hydrological changes in the past five decades. Changes in regional hydrology and ecosystem were analyzed using the simulated results, with a special focus on the understanding of the river discharge responses to climate variation and vegetation change in the Loess Plateau during the recent 30 years.

Keywords: eco-hydrological modeling, land use/cover change, climate change, regional hydrological change

Global River Flood Exposure Assessment under Climate and Socioeconomic Scenarios: How Many People Are Affected In Future?

Global River Flood Exposure Assessment under Climate and Socioeconomic Scenarios: How Many People Are Affected In Future?

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Floods are the most common natural disaster due to the frequency and intensity of heavy rainfall. In particular, human exposure to floods has been increasing to a greater extent in South Asia, East Asia, and Europe as well. This is likely to expand exposure of assets at risk and magnify flood risk, resulting in more human and economic damage, if population growth is sustained and valuable assets are continuously accumulated in river deltas. For global flood risk assessment, it is important to identify and characterize flood areas, locations, and durations. Thus, global flood mapping is an imperative process for risk management, as well as an effective tool for solving trans-boundary water issues at both national and international levels.
Although advanced hydrological inundation models have been developed and suggested that flood hazard, exposure, vulnerability, and risk are well revealed at the river basin to national levels, it is obviously hard to identify the distribution and locations of flood risk on the continent scale. The main concern is which parts in the Eurasian region can be found as high-risk areas in terms of population vulnerable to probabilistic 50-year cyclic flood events under the conditions of climate change and socio-economic scenarios, based on MRI-AGCM3.2S with the Representative Concentration Pathways (RCP8.5) emissions scenario.
In these regards, the purpose of this study is to propose an assessment method for flood exposure between the two periods, i.e., for Present (daily data from 1980 to 2004), and Future (daily data from 2075 to 2099), over the Eurasian region with a special interest in long-term changes due to climate change and socio-economic effects. We propose a methodological possibility to be used as a rapid flood exposure assessment despite low data availability. The method is designed to effectively simplify complexities caused by hydrological and topographical variables in a flood risk-prone area and then visually evaluate hazard occurrences and exposure under the condition of annual maximum daily river discharge with a 1/50 probability of occurrence.
The preliminary results show that inundation areas in Asia and Europe were identified as upward trends in both Present and Future by using GFID2M (global flood inundation depth 2-dimension model) that uses a rapid and straightforward method based on topographic calculation, and that the possible number of affected population may increase in the future by calculating with population change ratio from a distributed data of global population (Landscan 2009 by the Oak Ridge National Laboratory). As a result of the physical exposure assessment from Present and Future, potential hazards area and affected population are projected to occupy approximately 228,646 km^2 and approximately 305 million people respectively, because the population of Asia may increase by about 43% while that of Europe may decrease slightly in Future. Moreover, the results show that the cropland is likely to account for the largest proportion among the increased risk areas in Future in terms of socioeconomic impacts by probabilistic 50-year cyclic flood events.

キーワード：全球河川氾濫、洪水曝露人口、洪水浸水深、洪水影響人口

Keywords: Global river flood, Flood exposure, Flood inundation depth, Affected population

全球水資源モデルH08への高度な取水スキームの導入

Incorporation of advanced water abstraction schemes into the H08 global hydrological model

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水は社会に不可欠な資源である。しかし、水需要の増加、地下水の過剰くみ上げ、人為的な気候変化などにより、今世紀の地球水資源の持続可能性が懸念されている。このような地球規模水資源問題を定量的に分析するため、全球水資源モデルの開発が行われ、特に温暖化影響評価などにおいて大きな成果を上げてきた。H08はそうしたモデルの一つである。H08は地表面水文過程、河川流下、作物成長、取水、貯水池操作、環境用水の６つのサブモデルからなり、自然の水循環と人間の水利用を統合的にシミュレーションすることができる。今回、温暖化の適応策などを含むより高度なシミュレーションを実施するため、取水に関する６つの新たな機能を開発し、追加した。具体的には、地下水涵養、地下水取水、分水と導水、水利用効率と損失、改良された貯水池表現、海水淡水化である。本発表では、これらの機能を加えたことによる地球水循環シミュレーションへの効果や、地球水資源評価への示唆について紹介する。

キーワード：全球水文モデル
Keywords: Global Hydrological Model

High-resolution modeling of human and climate impacts on global water resources

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The number of global hydrological models (GHMs) have been developed in recent decades in order to understand the impacts of climate variability and human activities on water resources availability. The spatial resolution of GHMs is mostly constrained at a 0.5^{o} by 0.5^{o} grid (~50km by ~50km at the equator). However, for many of the water-related problems facing society, the current spatial scale of GHMs is insufficient to provide locally relevant information. Here, using the PCR-GLOBWB model we present for the first time the analysis of human and climate impacts on global water resources at a 0.1^{o} by 0.1^{o} grid (~10km by ~10km at the equator) in order to depict more precisely regional variability in water availability and use. Most model input data (topography, vegetation, soil properties, routing, human water use) have been parameterized at a 0.1^{o} global grid and feature a distinctively higher resolution. Distinct from many other GHMs, PCR-GLOBWB includes groundwater representation and simulates groundwater heads and lateral groundwater flows based on MODFLOW with existing geohydrological information. This study shows that global hydrological simulations at higher spatial resolutions are feasible for multi-decadal to century periods.

Keywords: Global water resources, Human impacts, Climate variability, Groundwater dynamics, High-resolution modeling

将来水需要シナリオを用いた水資源評価： Water Futures and Solutions (WFaS) initiative による事例

Development of future water use scenarios: Water Futures and Solutions (WFaS) initiative’s approaches

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Long-term and efficient strategies for water security have become increasingly important to achieve sustainable development. In order to explore practical development goals and pathways, a scenario-base approach provides valuable insights, since it can identify our challenges. However, still only few water resource assessments have considered “Shared Socioeconomic Pathways (SSPs)”. It is expected that water demand will increase in conjunction with population and economic growth. On the other hand, economic and technological progress have potential to improve water use efficiency leading to a reduction in water use. Water Future and Solutions (WFaS) aims to establish a comprehensive water assessment framework which covers agricultural-industrial-domestic sectors. The purpose of this study is to develop and analyze a set of consistent global water scenarios, especially about agricultural sector.
As a fast track, WFaS chose three sets of SSPs and Representative Concentration Pathway (RCPs), then developed global water narratives.
For agriculture sector, future trajectories of two key drivers were assumed; crop and irrigation area, and irrigation efficiency (*IE*) (Yearly, 2010-2099). It is expected that crop area and the area equipped for irrigation will expand over time. Irrigation area change reflects structural socioeconomic change such as food demand and land use. The Global Agro-ecological Zones (GAEZ) system provided a series of projection of spatial distribution of crop and irrigation area. GAEZ encompasses climate scenarios, demographic and socio-economic drivers, and production, consumption and world food trade dynamics.
WFaS provides dynamical scenarios of *IE* with a hypothesis that *IE* improves along with socio-economic growth, considering possible combinations of five crop types and three irrigation systems; gravity, sprinkler and drip irrigation. Each system has specific range of *IE*. The projection of *IE* was aggregated at country level to meet specification of existing global hydrological models. The country level *IE* will improves when an existing irrigation system is replaced with an innovated same irrigation system or another higher efficiency system, or an irrigation area expands with a higher efficiency system. Thus this study formulates the improvement of *IE* as a function of country/scenario-specific or system-specific parameters of replacement speed and a function of irrigation area. To define country/scenario-specific parameters, a country classification which is based on its socioeconomic condition and hydrological condition was

applied. For instance, a country who has less water resource and higher financial power shows more rapid improvement of *IE*.
Forced the three scenarios, three global water models (H08, PCR-GLOBWB, WaterGAP) projected and estimated future water supply and demand. As results of the projection, two water resource assessments which covers agricultural, industrial and domestic sectors will be presented. The first assessment is about imbalances between supply and demand, then hot spots of water scarcity is highlighted. For example in Asia, potential population under severe water scarcity will increase throughout all scenarios considered, in the range of 1.7 to 2.1 billion, which represents approximately 40% of Asia’s total population in the 2050s. The second assessment is a country classification from the view point of their cooping capacity and hydrological challenge. Our result suggests that Pakistan, Afghanistan, and Azerbaijan will remain the most vulnerable countries in Asia because they will be highly water stressed with low adaptive capacity under all scenarios. The number of people living in these three countries will total between 323 and 450 million people in the 2050s.

キーワード：全球水資源シナリオ、水需要、Shared Socioeconomic Pathways (SSPs)、全球水資源モデル
Keywords: Global water scenarios, Water demand, Shared Socioeconomic Pathways (SSPs), Global water model

Real and virtual water transfers in a Coupled Human-Water System Dynamics

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In China, a large amount of water is transferred among regions to mitigate regional water scarcity. Water can be relocated through water transfer projects and virtually, embodied water for the production of traded products. Here, we explore whether such water redistributions can help mitigate water stress in China. In this talk, a full inventory is investigated for physical and virtual water transfers at a provincial level in China. Our results show that, at the national level, physical water flows because of the major water transfer projects amounted to 4.5% of national water supply, whereas virtual water flows accounted for 35% (varies between 11% and 65%at the provincial level). Furthermore, our analysis shows that these transfers help mitigate water scarcity in several water-receiving regions, but they exacerbate water stress for the water-exporting regions of China. Future water stress in the main water-exporting provinces is likely to increase further based on our analysis of the historical trajectory of the major governing socioeconomic and technical factors and the full implementation of policy initiatives relating to water use and economic development. Improving water use efficiency is key to mitigating water stress, but the efficiency gains will be largely offset by the water demand increase caused by continued economic development. We conclude that much greater attention needs to be paid to water demand management rather than the current focus on supply-oriented management. In a coupled human-water system, human should rely on not only built water infrastructure (“grey” infrastructure), but also ecosystem-based “green” infrastructure to mitigate water scarcity.

Keywords: Water transfer, Virtual water, Water scarcity, Green infrastructure

Evolution of societal value on water for economic development and environmental sustainability in Australia during 1843-2011

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The stress on freshwater resources around the world cast by the human activities now as well as in future requires a radical paradigm shift in approaches to water resources management. Changes in values are seen as leading to changes in decisions and thus to changes in behaviour. However, societal value has not been addressed adequately in current water management studies.
This paper aims to understand the evolution of societal value on water resources for economic development and environmental sustainability in Australia. The Sydney Morning Herald was used as the data sources to track the changes of societal values on water resource between 1843 and 2011. Specifically, this paper will address the following three research questions:
1) How did the societal value on water for economic development verse environmental sustainability in Australia evolve over timescale of 169 years?
2) What was the transition pattern of the societal value?
3) In what context such transition occurs, and what factors possibly trigger such transition?
Three methods were used in this study include: 1) describing evolution of the societal value on water for economic development and environmental sustainability in Australia with the content analysis of newspaper; 2) determining the pattern of evolution of the societal value with both regression analysis and transition theory; 3) understanding the pattern of evolution of the societal value with co-evolutionary framework.
Overall, the importance of economic development has been declining with the arising attention given to environment. The vision for environmental sustainability were kept at a minimal level at the beginning, and stayed as a relatively low voice in the society until it took off at around 1960s and overweigh the voice of economic development in the last decade. The fitted sigmoid curve for societal value on economic development and societal value on environmental sustainability were regressed. According to the derivatives of these two equations, three stages were identified. The predevelopment stage of societal value on environmental sustainability when changes occurred only marginally was identified as the period during 1843-1961. The take-off stage was considered between 1962-1980. The take-off point was when the rate of change speed is maximized. The acceleration stage was identified during1981-2011. It is a period of the absolute value of societal value is still increasing, the acceleration rate is negative and the rate of change is decreasing. Around 2000 a new process of the acceleration rate increase started. The stabilization stage did not appear because the rate of change of societal value has not come to zero.
The societal value on water resources in Australia has co-evolved with the variability of rainfall, and management policies and practice reforms. The co-evolutionary processes are explained according to the stages of societal value transition identified above. They include the predevelopment (1900s-1960s)- societal value on water resources was dominated by economic development; take-off (1962-1980), societal value on water resources reflected increasing awareness of the environment due to outbreak of pollution events; 1980-2011: environment oriented societal value on water resources and the Millennium Drought triggered a package of policy initiatives and management practice towards sustainable water resource use.
This study developed a new method in combination of qualitative and quantitative approach to measure the change of societal value on water, a "less tangible" variable, and its transition pattern with time. Our study provided an understanding of the dynamical mechanism of transitions

which can assist policy makers to identify management practices that require improvement by understanding how today's conditions and problems were created in the past.

Keywords: Societal value change, Water resources managmeent, Content analysis of news paper, Social-hydrology, Social-ecological co-evolution

Understanding of feedback mechanisms of the introduction of new technology in rice farming from ecohydrological and social perspectives in heterogeneous farm households in Korea

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The agricultural institutes in Korea promote a new rice farming technology, so-called "wet-hill-direct-seeding". This technology would reduce the production costs as well as labor and prevent ear of rice from collapsing, resulting in better initial growth and rooting. However, the new method may result in uncertain consequences in term of ecohydrology and biogeochemical cycling. It also requires the application of herbicides, which may not be suitable for organic-farming. The younger generation of farmers are prone to adopt this new technology whereas the older prefer the conventional approach. The objective of this study is 1) to develop a model framework for the assessment of the feedback mechanisms of the introduction of new technology from ecohydrological and social perspectives and 2) to simulate the potential economic and environmental impacts of this technology over time in a community with heterogeneous farm-households. In this presentation, the framework of multi agent systems simulator is introduced, which include social systems defining specific behavioral processes of farm households, agricultural systems characterizing different management and ecohydrological conditions, and the interactions between two systems. In the context of climate-smart agriculture, various factors are considered such as decision-making, diffusion of technology, and environmental modules such as carbon-calculator, biotic and thermodynamic indicators. The expected outcome from this study is to better understand how new technology, market dynamics, environmental change and policy intervention affect a heterogeneous population of a local farm-households and the resources they command.

Keywords: climate smart agriculture, ecohydrological and social effects, multi agent systems modleing, rice farming , new technology

Unintended consequence of managing coupled humans and water in an arid landscape: irrigation efficiency paradox

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In the arid landscapes like northwestern China, water shortage is one of the most influencing factors to restrict the socio-economic development during its long history. Since 1990s, agricultural water-saving technology has been adopted as an effective long-term solution for severe water shortages. However, during 1998-2010, the irrigation water consumption experienced significant rising while irrigation efficiency increased evidently, which indicates the occurrence of so-called irrigation efficiency paradox (IEP). There exist a lot of studies which explore its economic side using theory of rebound effect. However, other sides like policy or institution, which could be more important to understand the interactions between humans and water, have not yet been explored. In this study, a long-term (1950-2010) agriculture development in Bayingolin is firstly analyzed to provide a general context of IEP occurring during 1998-2010 and to identity the key feedback loops between human and water. A conceptual socio-hydrological model has been developed aiming to capture the rebound effect of technology and adaptation effect of society. The model can be used to identify potentially sustainable policy for agricultural development and water management in arid landscapes.

Keywords: humans, irrigation efficiency, paradox, arid landscape

Finding a Sustainable Balance in the Water-Food-Environment Nexus: Socio-economic Transformation of an Agricultural Basin

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Freshwater security poses one of the major challenges of the 21st century, with future supplies uncertain due to climate change and increasing demands on water as populations grow and ecosystem services become increasingly valued. Increasing water use in agriculture inevitably reduces the share available for ecosystems, leading to its degradation, and in places where ecosystem services are valued by humans, community sentiment turns adverse. Water management decisions made that favour ecosystem sustainability can, however, impact a region’s economy, employment, and population, especially in agriculture centred economies. The competition for water threatens the viability of agricultural communities. The potential for conflict is self-evident as different users of water attempt to maximize their benefits at the expense of others. This paper focused on this water-food-environment nexus in the Murrumbidgee River Basin, Australia, and how it contributed to the evolution of the regional economy and changing demographic patterns. In the Murrumbidgee water management policies favouring the environment were implemented in the mid-1990s. Paradoxically, against expectations, unemployment in the region fell and there was an increase in average regional income, despite a decline in agriculture. To understand this, and to explore how the competition for water played out in the Murrumbidgee Basin, we developed and used a socio-hydrologic model that explicitly considers bi-directional feedbacks between human and water systems. The modelling simulated the change in community sentiment in response to widespread ecosystem degradation, and forced water management that favoured ecosystems which led to the inevitable decline in agriculture production. The model translated the impact of this decline to the remainder of the economy. The modelling showed how the basin economy reorganized through sectoral transformation to the manufacturing and service sectors, improved agricultural practices, and out-migration of basin residents. The sectoral transformation was facilitated by capital available for investment in manufacturing and service sectors with knock-on impacts on population dynamics and unemployment. The composite impact of sectoral transformation, out-migration and agriculture diversification cushioned the basin economy which adapted to cope with cuts to agricultural water allocations and collectively these contributed to a sustainable transformation of the basin economy. The dynamics outlined here highlight the adaptive capacity of people and movement of capital in a free economy, supported by appropriate strategies and funding, to cope with water stress. These findings are counter-intuitive and not self-evident without the use of the socio-hydrology analysis present in this paper. This type of modelling can be useful to assist the debate in other agriculture communities and beneficially inform how communities could transform and open up adaptation pathways. In a world where fresh water crisis is imminent it can further the understanding of why water management in some basins fail (Aral Sea, Unina Lake), while other basins like the Murrumbidgee are transforming and can help define the role of economic transformation in water management.

Keywords: ecosystem, economy, sectoral transformation, water allocation

水-人間系相互作用を考慮した技術社会における基本高水の改訂要因の抽出

Extracting Triggers of Design Flood Revisions to Capture Feedbacks between Physical and Social Processes in Technological Society

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In the era of the emergent Anthropocene, it is important to capture the feedbacks between physical and social processes [Savenije et al., 2014; Sivapalan, 2015]. In technological society [Di Baldassarre et al. 2015], flood mitigations and managements in a river basin are conducted based on a design flood (m^3/s) set by hydrological technologies: observations and modeling so on, and river structures (levees, dam reservoirs etc.) are designed based on the design flood.

In Japan, one of the typical technological society, modern hydrological technologies were imported by Dutch engineers in Meiji era (1868-1912), and modern flood prevention projects were started. The design floods of these projects were set based on the observed historical floods discharge, and the return periods of the design floods were about 20-30 years. However, after the era, the design floods have been revised many times and increased, and the flood prevention projects were also enhanced with increasing levees height and constructing dam reservoirs. Now, the return periods of design flood in Japanese main rivers are set as 150-200 years. The increasing tendency of design floods and enhancements of flood preventions have caused “levee effects” [Montz and Tobin, 2008]: enhancement of land use changes (increasing vulnerability for flooding), and increasing flood intensity [Takahashi, 1964].

As described above history, we hypothesize that the feedbacks in the technological society have been caused via design flood revisions, and conduct a survey for historical sources related Japanese flood prevention plans and design floods to extract the triggers of design flood revisions [Nakamura, S. and T. Oki, 2011]. In this presentation, we show a classification and historical transition of triggers of design flood revisions in Japan, in addition, discuss the mechanism of design flood revisions to capture feedbacks between physical and social processes in technological societies based on the survey result and other socio-hydrological data.

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キーワード：技術社会、基本高水、人新世
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