Leave it more to aquifer? Characterizing potential benefits and unintended consequences of weather index insurance on irrigated cropland

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Irrigation is commonly employed as the main strategy to maintain target crop production under climate fluctuations. Weather index insurance presents another mean to cope with climate uncertainty by providing farmers with additional financial resilience at low transaction cost, while avoiding moral hazard and adverse selection that plague traditional crop damage-based insurance. Thus, the integrated use of weather index insurance and irrigation has the potential to reduce groundwater use as irrigation presents a significant share of groundwater depletion. So far, however, weather index insurance has been used almost entirely on rain-fed cropland owing to technical difficulties in the conventional approach to insurance design. We propose an alternative approach to overcome these obstacles and demonstrate how to adopt weather index insurance optimally with available irrigation strategies from a financial perspective. This optimal result, however, may present either potential benefits or unintended consequences for aquifer management.

Keywords: weather index insurance, irrigation, groundwater

Reconstruction of the Thermal Environment Evolution from Subsurface Temperature Distribution in Asian and European Mega cities

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We have been investigating subsurface temperature profiles in several Mega cities for reconstruct the past ground surface temperature (GST), including Tokyo area, Osaka area, Bangkok area, and Berlin area. We examined the shapes of the subsurface temperature profiles and selected ones that are not significantly disturbed by groundwater flow. Reconstruction of GST history for the last several hundred years was made at two sites in the Tokyo area, at six sites in the Osaka area, at six sites in the Bangkok area, and at eight sites in the Berlin area. We used a multi-layer model that allows layers with different thermal properties, determining layer boundaries based on lithology of the formations around the wells. We assumed that temperature variations propagate by only thermal diffusion into the subsurface.

All of the reconstructed GST histories show surface warming in the last century. The GSTs increase ranges from 0.4 to 5.0 K varies by sites. The tendency is that the GSTs increase in the city area are larger than those of rural area. This tendency may reflect difference in the degree of urbanization or human activities.

Keywords: subsurafce warming, heat island effect, global warming, ground surface temperature, urbanization

On the thresholds of withdrawal-to-availability ratio: a perspective from a global hydrological simulation including groundwater

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Withdrawal to availability ratio (WTA) is a widely accepted empirical index to express water stress in the world. It accompanies two empirical thresholds or the regions where WTA exceeds 0.2 and 0.4 are categorized as medium and high water stress respectively, but the rationale of these thresholds has been little explained. Here we show these thresholds are linked with physical water scarcity using a state of the art global hydrological model. The model enables us to simulate global water supply and demand at the spatial resolution of 0.5˚×0.5˚ at a daily temporal interval with distinction of seven water sources including groundwater. From the simulation results, we obtained the relationship between WTA and the fraction of water abstraction from local and renewable sources to all (FLRE). We found that when WTA exceeds 0.2 and 0.4, FLRE shows a sudden drop in FLRE or the regions require additional non-local and/or nonrenewable water sources. The results support the general validity of WTA and the threshold as an index to assess water scarcity. At the same time, they also call the users attention that considerable spread between WTA and FLRE: WTA could be a surrogate of FLRE in limited extent

Keywords: water resources

Groundwater over-exploitation and terrestrial water storage change: A global analysis using hydrological models and GRACE

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In this study, we use different spherical harmonic products from the gravity recovery and climate experiment (GRACE) satellite mission and the results from two state-of-the-art hydrological models that explicitly simulate groundwater extractions to (1) examine the variations in terrestrial water storage (TWS) and its individual components, (2) attribute the changes in TWS to natural and human-induced factors, especially groundwater overexploitation, over a range of global river basins, and (3) assess the performance of different GW schemes incorporated in two models. Analysis of the spatial patterns of the long-term trend in TWS from the two models and GRACE suggests that both models capture the GRACE-measured direction of change, but differ from GRACE as well as among each other in terms of the magnitude over different global regions. A detailed analysis of the seasonal cycle of TWS variations shows notable differences not only between models and GRACE but also among different GRACE products and between the two models. The isolation of natural and human-induced changes in TWS in some of the managed basins reveals a consistently declining TWS trend during 2002-2010 caused primarily by groundwater overexploitation, however; significant differences are again obvious both between GRACE and models and among different GRACE products and models. Results from the decomposition of the TWS signal into the general trend and seasonality indicate that while one model doesn’t capture the long-term trend which dominates the original time series over the basins impacted by continuous drought and long-term GW storage depletion, the other model fails to estimate the seasonality in snow-dominated basins.

Keywords: Groundwater over-exploitation , Terrestrial water storage, Hydrological models, GRACE, Human impacts

Simulating large-scale groundwater table fluctuations : An application to the Community Water Model (CWATM)

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Groundwater is widely utilized as a valuable water resource, and currently, more than one-quarter of global population heavily relies on groundwater. Recently, many studies report depletion of groundwater resources due to overexploitation, especially in major irrigated areas and highly populated areas, indicating the use is no longer sustainable. The pressure to groundwater resource will increase in future, as it is expected that water demands will increase driven by a growing population and economic development. Climate change will also affect water availability and groundwater recharge. Thus it is an urgent issue to assess and appropriately manage groundwater resource, regarding water and food security and sustainable development. Also, groundwater plays a significant role in the hydrological cycle, and it is indispensable for the ecological and biophysical cycle.

Studies of groundwater dynamics at the global scale are significant in order to understand global environmental issues. They require a better understanding of impacts of changing the climate and anthropogenic activity, such as groundwater pumping and land use change, and feedback to them. Although there are numbers of local or regional studies that discuss groundwater dynamics with models, such as LEAFHYDRO and MODFLOW, however, still only few global models can represent the depletion of groundwater resource. To our knowledge, two hydrological models (PCR-GLOBWB, WaterGAP2.2a) can simulate variability of groundwater storage and two land surface models HiGW-MAT and MATSIRO-GW represents dynamics of groundwater table.

The purpose of this study is to introduce dynamic groundwater scheme into the Community Water Model (CWATM), a global hydrological model, which is able to assess changes in accessibility to groundwater resource and to investigate its impact on water and heat exchange at the surface through soil moisture, simulating the dynamic behavior of groundwater table. As well as the groundwater table, CWATM is going to include water quality module and hydro-economic module to provide a portfolio of economically optimal solutions for future water problems. CWATM is an integrated global hydrological model developed to assess how water availability and water demand will look in future under changing climate and socio-economic condition. Therefore it includes both components and it is designed to run at different scales from local to global. CWATM is open source and a community-driven model. Thus its specification is user-friendly and flexible enough to implement/link new modules.

The dynamic groundwater table scheme is developed as an external module of current CWATM’s hydrological module. Originally, it has a groundwater reservoir under three soil layers. The explicit description of groundwater table variabilities enables us to quantify deterioration of accessibility to groundwater resource. Eventually, with hundreds-years long-term simulations, this modeling framework will provide insights of past and future impacts of climate change and anthropogenic activities on the variability of groundwater table, respectively. Taking the accessibility to groundwater resource into account, we will evaluate how effective solutions are to decrease water demand, such as improvement of water use efficiency and better timing of groundwater use to control groundwater table depression. Furthermore, given these solutions, the assessment is going to reveal a time scale to restore depressed

groundwater to its sound state to achieve sustainable water use.

Keywords: Groundwater resource, Groundwater table, Global model, Climate change, Anthropogenic impact

On the behavior of reservoir operation in a global hydrological model under multiple meteorological forcing

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We performed an intercomparison of simulated river discharge using the H08 hydrological model with four meteorological forcing datasets to investigate regulatory dam functions on river flow. An intensive case-study was performed at Fort Peck Dam on the Missouri River. Results demonstrated that dam-regulated river flow reduces the temporal variability for large time periods (smoothing effects). Consequently, this dampened the natural variability present within the meteorological forcing data. We also observed that during wet years, occasional floods pass through the dam control. This was attributed to simulated dam overflow and resulted in a distinctive hydrograph shape downstream of the dam (pulsing effects), which created divergences between simulated peak flow discharges for the different meteorological datasets. To confirm whether the pulsing effects were commonly seen globally, we evaluated other major dam sites. The results showed that the differences in the magnitude of simulated peak flow between the meteorological forcing datasets increased downstream at 37 of 47 global major dam sites for wet years. Depending upon the meteorological forcing data, dams act as a selective filter against peak flow events. That is, dams nonlinearly magnified differences in meteorological data and produced large uncertainties in regulated river discharge primarily downstream of dams.

Keywords: water resources, dam

