

Impact assessment of the Seto-Inland Sea Water Profile Based on CMIP5 Model Ensemble

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1.Introduction

This study uses the Regional Ocean Modeling System (ROMS) to project environmental changes of the Seto-Inland Sea in Japan based on the Coupled Model Intercomparison Project Phase 5 (CMIP5) ensemble. The IPCC-AR5 WGI (referred to as AR5) was published in September 2013 and made great progress in impact assessment for future climate changes. Uncertainty of these future projections can mostly be attributed to either greenhouse gas emission scenarios or the precision of the projection model (e.g. GCM). Emission scenarios such as Representative Concentration Pathways (RCP) have been considered and the uncertainty in the model is assessed by the model ensemble mean, which assumes that results are scattered around the true value (IPCC, 2013). Although there are many impact assessments on global or large scale changes in the coastal ocean environment, there are few studies on smaller scale changes, for example in Japan. Further, examination of local scale change has not been consistently discussed in the AR5 large scale impact assessment.

This study analyzed CMIP5 for near-sea surface global and local ocean areas. It also examined the projection of physical environmental changes of the Seto-Inland Sea in Japan by numerical downscaling with CMIP5 forcing.

2.Analysis of CMIP5

CMIP5 was analyzed for present climate named historical, future climate named RCP 4.5W/m² scenario (RCP4.5) and RCP8.5. It focused on ten ocean areas, including global areas and locations in east Japan (E125 degrees-E136 degrees, N27 degrees-N35 degrees). The objective variables of CMIP5 are atmospheric temperature, cloud fraction, humidity, wind speed, sea level pressure, shortwave radiation and longwave radiation, which were analyzed by a 61 GCMs ensemble. Spatial distribution of sea surface temperature (SST) showed a consistent increase overall, with local non-homogeneity; for example, analysis projects an increase greater than 4 degrees increase in the northwest Pacific. The monthly mean of SST in west Japan was projected to change with a maximum increase of 3.5 degrees in June and 2.8 degrees in January. The projected increase is higher than that of the global annual mean. While a constant cloud fraction is projected on the global scale, the model projects a decrease in cloud fraction in west Japan.

3.Future Change of Water Profile in the Seto-Inland Sea

This study calculated the long-term analysis as 2093 using ROMS as downscaling model with forcing variables from CMIP5 results to project future environmental changes in west Japan's Seto-Inland Sea. The projection results in present climate condition were compared with observed results (Tanaka et al., 2013) similarly calculated in 2004. Topography data was taken from Japan GSI, with 1km resolution. Lateral boundary conditions were obtained from FRA-JCOPE. The atmospheric conditions were implemented using hourly results of CMIP5 analysis for temperature, SLP, short wave radiation, cloud fraction and wind speed. In the summer, the SST shows a remarkable increase of about 1.6 degrees. An increase of the same kind of water profile was projected in both shallow and deep areas of Hiuchinada and Kitan straits. A difference between the areas is increasing trend near the sea surface. Remarkable warming near sea surface in Hiuchinada contrasts with constant warming over all layers in Kitan straits.

4.Conclusions

CMIP5 analysis projected a decrease in cloud fraction in the western part of Japan despite projecting a constant cloud fraction on the global scale. Furthermore, although results project an increase in short wave radiation in west Japan. They project a global average decrease.

Using ROMS with forcing from CMIP5 analysis projected an SST increase of 1.6 degrees in the summer. Finally, the water profile tends to remarkably increase in shallow water, such as in Hiuchinada.

Keywords: the Seto-Inland Sea, water profile, ROMS, CMIP5, cloud fraction, short wave radiation

Study on origin of high- pH spring in Yuzawa Geopark, Akita

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Yuzawa Geopark, located in the southeastern part of Akita prefecture, is famous for geothermal activity and various types of hot springs. In addition, there are many springs that are recharged by huge amount of snow in this area. A high-pH spring (pH>9) is located in a Neogene hill. There is no hydrological study on the high-pH spring. Therefore, this study aims to clarify the origin and groundwater quality evolution process of the high-pH spring. We will show the results of major dissolved ions and stable isotopes of springs that were collected in September and November of 2014.

The high-pH spring discharges from joint of Neogene clay layer, and white deposit (calcite?) was found in the joint around of discharge point. pH and EC of the high-pH spring were 9.7 to 9.9 and 460 to 480 $\mu\text{S}/\text{cm}$, respectively. Groundwater quality showed Na-HCO₃ type. As for $\delta^{18}\text{O}$ and δD , the high-pH spring was located along local meteoric water line (d=20). Considering the correlation between isotopic ratios and elevation of discharge points that were obtained from the springs that were collected in wide area of the geopark, elevation of the recharge area of the high-pH spring was estimated more than 400 masl. However, this value was much higher than the elevation of topographical recharge area of the high-pH spring. The results of this study suggest that the high-pH spring may be recharged by regional groundwater flow system and may have long travel time.

Keywords: high-pH spring, multi tracer, environmental isotopes, Yuzawa geopark

A prompt report on influence and change on the river of around Mt.Ontake after eruption (140927)

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1.Introduction

Mt.Ontake located in the boundary of Nagano and Gifu erupted by phreatic explosion at about 11:53 a.m. on September 27, 2014. The volcanic ejecta which occurred by this eruption gets into the lake and the outskirts river of the mountaintop neighborhood, so naturally influence on water environment is thought about. Therefore our laboratory started a continuation investigation to check a change of the water environment of a river around Mt.Ontake by the eruption.

2.Survey method

The field work item is AT,WT,pH,RpH,EC. In addition, I performed the water quality measurement of the plumb direction using ALEC at some spots. Furthermore, I collect water and take a sample home with me and analyze TOC, major dissolved component in a laboratory.

3.A result and consideration

Volcanic ejecta flowed in Nigori river of the crater south side of Mt.Ontake and Outaki river after the Nigori river junction, and river water was able to observe a cloudy state. From result of a measurement of pH, the around Mt.Ontake river became the value before and after 7.0 generally, but showed a value before and after 3.5 and the strong acidity at the cloudy spot. In addition, the value of the EC is less than 20 mS/cm generally, too, but a value is big at the cloudy spot, and a value called 170 mS/cm is observed in Nigori river just after the eruption.

There is not a cloudy state, and a value of pH is around 7.0 in the river of the east side of Mt.Ontake. But a value of the EC is slightly big in a part river. In addition, with the Nobunaga Bridge whom there was near a mountain rising to a great height ropeway, pH was around 4.5 values and the value of the EC was relatively big. So I knew that influence of the eruption appeared on the east side of Mt.Ontake particularly in mountaintop neighborhood

The cloudy river water of Outaki river flows into the Ontake Lake made by a dam. As for the surface water of the Ontake Lake and a spot more downstream than the Ontake Lake, there was no great difference between pH, EC and the whole around Mt.Ontake river together at the stage of the investigation of October 8 just after the eruption. But when it was on October 31, a drop of pH and a rise of the EC were confirmed, and a similar change was seen. The volcanic ejecta which flowed into the Ontake Lake only deposited in the bottom of a lake at the stage of October 8, but I have lake water cycle in the Ontake Lake from here to October 31, and influence of the volcanic ejecta of the bottom of a lake appears in the whole lake, and it can call that such a water is discharged by the dam, and a change appeared in the downstream water.

4.Conclusion

Influence and a change to the quality of the water of the around Mount Ontake river by the eruption became clear. I continue an investigation and investigate the crater lake of source area and the Mitake mountaintop as much as possible and will examine influence of the eruption more in future.

Keywords: Mt.Ontake, eruption, volcanic product, Ontake Lake, matter cycle

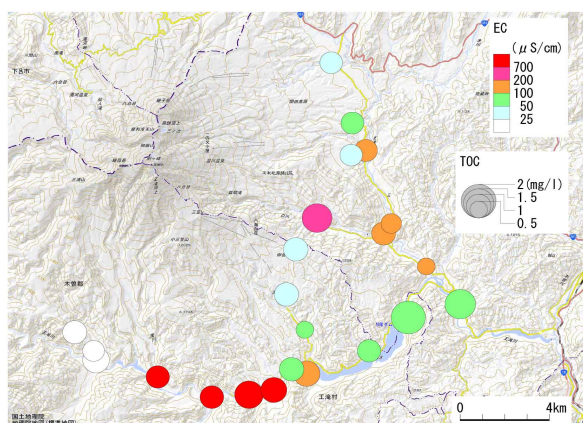


figure1 Distribution of EC and TOC

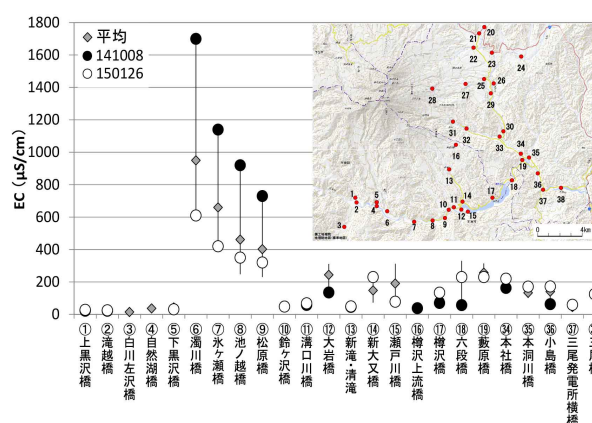


figure2 Drifting of EC(Outaki river)

Loading Processes of Chemical Matters in a Forested River Catchment : Observations and Modeling

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River water is one of the most important natural resource for our live and has much influence for lake and the earth because of fast transport velocity. Especially, outflow of chemical matters in river is related with river ecosystem and make lake eutrophication. We targeted Oikamanai river basin, forested catchment in Hokkaido. In this catchment, landuse is 88.3 % forest and 10.6 % farmland. Geology is the Neogene Miocene mud and sand stone, half of which is composed by marine deposit. We got the data on concentration of chemical matters and time series of discharge, electric conductivity (EC) and MET data. Fresh water's EC monitoring is new technology, so there are few reports. In this study, we calculated time series of concentration of chemical matters and chemical matters load using co-relation of concentration of chemical matters and EC. We analyzed discharge route using Tank-model. Using this result, we calculated chemical matters load at each discharge route. We discuss mechanism of outflow of chemical matters in forested catchment with these data.

In this study, we targeted Mg^{2+} , Ca^{2+} , Na^{+} , SO_4^{2-} , HCO_3^{-} because they have much influence for EC. As a result of Tank-model, baseflow is distinguished, 68.3 % and surfaceflow is distinguished in high discharge events. HCO_3^{-} analysis intended soil water tend to cultivate to underground. HCO_3^{-} was more dissolved in river water in high discharge events, this is insisted to be caused by river erosion. SO_4^{2-} analysis showed iron pyrites is oxidized in weathered mantle and upper basin and organic matters is bitten by microbe. Ca^{2+} , Na^{+} , Mg^{2+} analysis suggested ionic exchange with H^{+} occur in soil.

Keywords: forested river basin, chemical matter, Tank-model, L-Q equation

Evaluation of Land cover change and Flow regime change in upper area of Dong Nai river basin, Vietnam

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Vietnam is considered as one of the top countries to be severely affected by climate change, particularly in coastal areas. That by 1 m sea level rises, Vietnam would lead to flooding of up to 20,000 km² of the Mekong river delta and more than 1 million people would be directly affected in there and it is also predicted economic loss up to 10% GDP (Dasgupta *et al.*, 2007). In rainy season a combine of SLR and rainfall increase to make a serious impact on low-lying coastal areas. It is also predicted that 40,000 km² of coastal delta region, 90% of the Mekong delta will flood (Eastham *et al.*, 2008) and temperature is more significantly rise in the plateau region (MONRE, 2012).

Dong Nai river and Mekong delta downstream are located in and supplied the major water resources to the whole Southern of Vietnam. Continuous changes in water resources due to climate changes and several controversies about the potential impact of sediment transport and river flows downstream due to either the cascade hydroelectric power plant system or dam construction in the upper of Mekong delta being continuous. In addition, water resources from Dong Nai river is the resource that only controlled by Vietnam. On the other hand, solving the problems of water shortage in the dry season and flood control in rainy season are also important for issues of water management at Dong Nai river basin. Therefore evaluation of flow regime change by the affect of climate change and human activities is an urgent issue in Vietnam.

That forest area decreased as a human activity is the big problem in Vietnam. In the period from 2002 to 2009, 620 km² of forest land lost on average per year and 250 km² of forest land was converted to other land use (Vietnam Forest Protection Agency, 2010). The main reasons of deforestation are unsustainable logging and agricultural land development (Hoang M. H. *et al.*, 2010). In most cases the forest vegetation lost, runoff increases conversely forest vegetation growing, runoff often decreases (Maita and Suzuki, 2008).

The river flow regime was analyzed from 1989 to 2009 runoff data at 3 observation stations in study area. The Landsat images in 2014 and 2005 were used to classify to 5 majors of land cover such as the dense-forest, spare-forest, crop-land, bare-land and water body.

Dong Nai river basin area is 14,713.5km² with the main land cover types are dense-forest 35%, spare-forest 26% and cropland 24% in 2005. From 2005 to 2014, the large area of forest (both in dense and spare) was converted to crop-land and bare-land; a part of spare-forest had became dense-forest. Especially the majority of bare-land (7%) had been converted into the other land cove types. The ratio land cover was dense-forest 33%, spare-forest 16% and cropland 39%. We can see that deforestation has occurred in the study area from 2005 to present.

As the inflow of Tri An dam, the flow regime at Tri An (basin outlet) slightly increased in all the flow rates of normal discharge, low-water flow and drought flow but slightly decreased in hosui flow. Flow regime of Ta Lai point, where affected by deforestation, hosui flow and normal discharge is slightly increased but change trend of low-water flow and drought flow were not observed. As the inflow of upper stream dam, the flow regime at Da Nhim increased in all the flow rates of hosui flow, normal discharge, low-water flow and drought flow.

Keywords: Dong Nai river basin, Flow regime, Land cover change

Characteristics of groundwater temperature distribution of deep wells in Aizu basin

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The Shibasaki Laboratory of Fukushima University has conducted a joint research, 'Analysis on Geological Structure of Quaternary and Hydrological Structure in Aizu basin' with the Shallow Geothermal and Hydrogeology Team, AIST. The laboratory has carried out studies on groundwater flow and groundwater temperature. Considering popularization of ground-source heat utilization system, comprehension of groundwater flow will be able to design more efficient system.

In this study, we collected continuous monitoring data of groundwater level and groundwater temperature. We also measured pumped water temperature and its quality from sprinkling snow-melting wells, and depth-wise temperature at an interval of 2 m in deep wells.

Groundwater level of deep wells and some shallow wells showed reduction of groundwater levels in winter. This is because snow-melting wells were operating. Most of their depths range from 150 to 200 m and their strainers are installed at multiple layers, so groundwater is pumped from several aquifers. Groundwater temperature of snow-melting wells found to be higher in the eastern part of Aizu basin. The similar trend was identified in temperature distribution maps prepared by Kaneko et al. (2014).

There are some snow-melting wells with artesian flow at the periphery of Aizu Basin and their temperatures are higher than the neighboring snow-melting wells. This is because upward movement of groundwater occurs in artesian wells. In general, temperature should be higher in the western part of the central Aizu basin which lies in downstream area. However, groundwater temperature was higher in eastern part.

Moreover, snow-melting wells in the eastern part of the basin showed higher temperature, although there is no artesian flow. In these places, the thickness of Quaternary system is small and groundwater may be pumped from not only Quaternary system but also Neogene system.

For further investigation, we will examine chemical composition of groundwater by ion chromatography.

Modeling of Surface Water and Groundwater Cycle System in a Mountainous Catchment Underlain by Granite

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A mountainous watershed plays an important role as a recharge area, and many studies have been conducted regarding the groundwater flow. However, there have not been enough studies in headwater catchment with large topographical relief. Also, there have been few studies applying numerical simulation to the groundwater flow in the headwater catchment. Therefore, the aim of this study is to reproduce groundwater flow in a steep mountainous catchment underlain by granite using numerical simulation.

The study area is the headwater catchment of Jingu River in Yamanashi, which is one of the mountainous catchments underlain by granite. The highest relative height of the catchment is about 1400 m. The numerical simulator is GETFLOWS, which can analyze three dimensional surface and groundwater flow. In this study area, residence time and recharge altitude of groundwater have been estimated using CFCs and stable isotopes tracers previously, and this study aims to reproduce those values by numerical simulation.

The permeability was examined, and trials of reproduction of the groundwater flow system were performed. The permeability seems to have an effect on the groundwater flow system such as groundwater level and flow path. Also, in the north of the catchment, it has been found that several springs have longer residence time estimated by CFCs than the others have, and the similar result was shown by numerical simulation. Furthermore, the recharge altitude of springs showed appropriate values except some springs.

Keywords: groundwater, simulation, GETFLOWS, residence time, recharge altitude

Spatial analytic reasons of eutrophication in Baiyangdian Basin, China

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Baiyangdian is the closed lake located in North China Plain, about 150 km to the south of Beijing. The lake provides domestic and industrial water to surrounding area. The lake has functions of flood mitigation, water purification, conservation of biodiversity, that is ecosystem services. However, water shortage and pollution becomes serious problem, and ecosystem services are deteriorated.

Recent economical development in China leads increase in local industries, and population is increasing in the surrounding area. Water demand is also increasing, that lead to decreased storage and dry up of Baiyangdian lake.

Baiyangdian collects nine streams from Taihangshan mountains and effluent stream flows into Bohai Bay. Swamp area include about 3,700 of creeks connecting 146 water areas through channels. Total area is about 366 km² including 36 villages in the swamp area. The climate is temperate monsoon climate, which has dry and cold winter, and hot and moist summer. Average annual precipitation is 563.9 mm, and annual average pan evaporation reaches 1369 mm. About 80% of precipitation is concentrated from June to September.

Baiyangdian as natural wetland has many functions, namely ecosystem services. Proper conservation is required to maintain local agriculture and industries. The final goal of the study is conservation of ecosystem services of natural wetland. In this paper, we report the interannual and seasonal changes in water area and wetland vegetation in Baiyangdian by using satellite remote sensing. Field survey of water quality had conducted in 2010. The relationship between the condition of surface water and vegetation and water quality is investigated.

China 1km Mesh Grid Land Cover data in 1980 and 2000 shows the residential land and industrial land increased in Baiyangdian, and the arable land in the middle and mountain areas tend to increase, but decrease in plain area. Reduction of arable land area corresponds to the residential and industrial land increased area.

In addition, Water area and vegetated area in the lake has a decreasing tendency between 1989 and 2001. This is caused by housing and agricultural developments in the reclaimed land. Especially the upper part of Baiyangdian suffers development activities. On the other hand, it is proved that large water areas of Baiyangdian had been separated.

Field survey was carried out on April, June and September in 2010. Total nitrogen, total phosphorus, nitrate-nitrogen were measured at plural sampling points. The concentrations of the items are high at the inlet channel of Baiyangdian lake. It seems wetland vegetation (mainly reed grass) absorb the nutrients. The concentration in September is the lowest in the season. This is considered to be the absorption of the nutrients by vegetation in the growing season. It remains as the next point to discussion. Moreover, the observation months results are compared. The absorption rate of the nutrients in September is more high than it in April and June. One the reasons is that reed grass absorb the nutrients in the growing season from April to July. In addition, the transparency at inlet is much lower than center and outlet. The concentration distribution and the seasons change of water projects, are based on the pollutants from the upper steam, wetland vegetation purification function and the seasonal distribution of precipitation to illustrate.

Baiyangdian is a enclosed water which is near to the city, and solve the problems about enclosed water is the world common project. For example, in Japan, they are using Water Pollution Prevention Law and Lake Water Quality Prevention Measure to improve the water quality. In the future, the research of comparative hydrology based on around the world about enclosed water subject, to master the lake water environment problems as the earth in environment problems.

Keywords: Ecosystem services, Water pollution, Water area, Wetland vegetation

Hydrological Environment of Surface Water and Groundwater in Ninh Thuan Region, South-east Coast, Vietnam

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The Government of Vietnam is planning to construct two nuclear power plants in Ninh Thuan province, a coastal region of Vietnam with semi-arid climate conditions. This research aims to investigate the hydrological environment of surface water and groundwater in the planned site of Ninh Thuan 2 in order to obtain basic information for the construction of the plant. Inorganic solute ion concentrations and stable isotopes of oxygen and hydrogen in surface water, groundwater and seawater were analyzed to understand their chemical characteristics and hydrological process. The results demonstrate that water resources in this region are limited and groundwater is considered to be a main water source. The groundwater flows in Holocene and Pleistocene aquifers, with the depths of 10 m and 16-21 m, respectively and the dominant flow is from southwest to northeast, corresponding to the river flow direction in this area. There seems to be an interaction of surface water and groundwater in this region. Streams and wells near the shoreline are affected by brackish water with high Na-Cl concentration. Groundwater in the Holocene aquifer shows a chemical characteristic of Ca-SO₄ and Ca-HCO₃ type, whereas Na-HCO₃ water type is dominant in the Pleistocene aquifer. The water chemistry is being influenced by freshwater - brackish water mixing, weathering processes and human activities. The nitrate concentration of groundwater in the Holocene aquifer is higher than that in the Pleistocene aquifer, and much higher than WHO drinking water standards. This means that water in this region is affected by agricultural production activities. Therefore, the project developer should have a careful consideration when consuming water in this region for Ninh Thuan 2 nuclear power plant project.

Keywords: nuclear power plant, environmental impact assessment, water resources

The origin and formation mechanism of the water quality of deep hot springs from the northern foothills of Mt. Fuji

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Since the mid-1990s, drilling wells for hot spring bathing purpose was performed on a deep aquifer at depths reaching 1,500m below the surface in the northern foothills of Mt. Fuji. Meanwhile, the origins of the water and the formation mechanisms of the water qualities have not always been investigated thoroughly. Clarification of the forming environment of the hot spring waters is indispensable for the protection and sustainable development of hot spring sources.

In this study, water samples were collected from wells for hot spring bathing purposes and from natural springs in the northern foothills of Mt. Fuji and the adjacent Misaka and Tanzawa Mountains area, and were subjected to chemical and isotopic analysis of hydrogen, oxygen, and sulfur (δD , $\delta^{18}O$, $\delta^{34}S$). Based on the analytical results, the origin of the water and water-rock interactions, which affect the water quality of the deep hot springs, were discussed.

The water in samples were thought to be originated through mixing of meteoric water with very small amounts of altered seawater, which had been trapped in the pore space in the basement rock, so-called green tuff formation. After subtraction of the seawater-derived components, concentrations of major components of the water samples were thought to be controlled by the dissolution of gypsum and/or anhydrite, calcite precipitation, and the formation of Na-smectite by weathering of albitized plagioclase. Around the distribution areas of volcanic products of Mt. Fuji, the weathering process of olivine may also influence the concentrations of Mg^{2+} ions. The $\delta^{34}S$ values of SO_4^{2-} ions of hot spring waters were higher on the Misaka and Tanzawa Mountains side, whereas they were lower on the foot of Mt. Fuji side (down to +8.2 ‰), indicating the presence of different SO_4^{2-} ion sources; the former SO_4^{2-} ions with high SO_4^{2-} values are derived from marine anhydrite and/or gypsum, whereas the latter SO_4^{2-} ions with low $\delta^{34}S$ values are involved in volcanic anhydrite and/or gypsum.

Keywords: northern foothills of Mt. Fuji, deep hot spring, water quality, water-rock interaction, stable isotope ratio

Historical Rainfall, Runoff and Flood of Wadi Siham Basin, Yemen

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Wadi Siham Basin (WSB) is one of the most important agricultural areas, and one of the seven largest wadis in the western region of the Republic of Yemen. This study aims to evaluate the quantity and spatial and temporal variation of rainfall and runoff. The rainfall (1979-2008) as well as runoff and floods (1990-2009) data were collected and treated statistically in order to evaluate the rainfall and runoff trends. The areal catchment rainfall was estimated by using the Thiessen polygon method, while the recurrence interval and probability analysis were carried out using the Hazen method. The Mann-Kendall and Sen's slope analyses results showed that the Wallan and Al-Amir stations produced significant negative values (-4.72 and -6.11 mm/year respectively). However, the rainfall trend in Dhamar had a significant positive value of 50.20 mm/year. The average annual rainfall in WSB was 346.39 mm/year. The total amount of rainfall was 1711.26 Mm³. The mean annual water runoff was 82.92 Mm³. A total of 570 events of flood occurred with a total volume of 53.10 Mm³. The total water runoff was 4.85% of total rain precipitated on WSB indicating that the total amount of water loss was 95.15% varied between evapotranspiration and infiltration. In conclusion, the study results suggested the need for an urgent and sustainable water resource management in WSB.

Keywords: Rainfall, Runoff, Flood, Mann Kendal Test, Wadi Siham, Yemen

The characteristics of mercury deposition on to forest ecosystem observed in Yakushima Island

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Mercury (Hg) is a global pollutant that affects human and ecosystem health. Atmospheric Hg can be removed from the atmosphere by wet or dry deposition. Many studies suggest that the interactions between atmospheric Hg and the forest canopy may be a key process influencing Hg input to forested watersheds. These studies are mainly conducted in Europe, however, only a few studies were reported in Asian monsoonal area. The characteristics of the seasonal variation of a precipitation is different between Asian monsoonal area and Europe region, i.e., there is a rainy season (June-July) and typhoon season (July-September) in Asian monsoonal area. It has been reported that the most of atmospheric mercury is supplied as a wet deposition. Therefore, it is important to evaluate the characteristics of Hg atmospheric deposition in Asian monsoonal area. Yakushima island has more than 8,000 mm of annual precipitation. Therefore, it is suitable site to evaluate the mercury dynamics in the forest ecosystem.

Study sites are located at a height of 200 m and 1600 m above sea level of the broad-leaved evergreen forest in the western area of Yakushima Island, respectively. In 200 m experimental site, the experiment was conducted at a 100 m x 100 m experimental site around the observation tower. We installed automatic rain samplers which can collect rain water every 10 mm precipitation, bulk deposit samplers (within canopy and without canopy) and groundwater collecting devise, respectively. In addition, we sampled stream water which flow down near the observation tower. In 1600 m experimental site, we installed automatic rain samplers. These experiments are conducted during 2011-2014 sampling campaign and each samples are collected once a month basis. Hg, major ions, and DOC were analyzed. From these result we will discuss the characteristics of Hg deposition in Yakushima Island.

Keywords: Yakusima, mercury, forest ecosystem, Asia monsoon, precipitation

Study on a numerical model for fluid flow and heat transport through permeable porous media

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Interaction between the atmosphere, the surface and the subsurface is one of the most important keys in understanding, managing and utilizing the water environment. Recently, technologies for estimating the shallow subsurface thermal environment adequately are required along with the popularization of the ground-coupled heat pump system and the heating and cooling system by direct use of groundwater. A numerical simulation model for being able to estimate processes of fluid flow and thermal transport in unsaturated and high permeable porous media is required in order to develop the technique of shallow geothermal energy utilization.

In this study, the one-dimensional infiltration experiments using a cylinder column and improving the numerical simulation model were carried out. In the experiment, highly permeable porous media 3 and 5 millimeters in diameter were used. The flow velocity and the temperature changes in the column were measured. The experimental results were represented by the numerical model.

As the results, the high-velocity flow in the permeable porous media was simulated by the model using multi-phases system. In addition, in the model the temperature of soil, liquid (water) and air were able to be simulated individually and the calculated results were agreement with the experimental results.

Potential map of Borehole Heat Exchanger system for the central part of Kanto Plain and the Obama Plain

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A Borehole heat exchanger (BHE) is an economically and environmentally friendly technology that is widely used in Europe and North America, but rarely used in Japan. One of the reasons for this is the relatively complex topography and geological structure in Japan compared with those in Europe and North America.

Complex structures produce regional differences in subsurface thermal properties and temperature structures, leading to regional variation in the efficiency of BHEs. Thus, it is important to evaluate the available subsurface heat energy through thermal response tests and/or numerical simulations and to design appropriate systems (depth and number of boreholes for heat exchange). Geological structures, groundwater properties, and subsurface temperatures are essential input data for numerical simulations.

We performed BHE numerical simulations using measured data and present a new method for constructing a BHE potential map from regional geological structure models for typical Japanese plains. Our target areas are the central part of the Kanto Plain and the Obama Plain. The Kanto Plain contains the capital city of Japan and has a population of more than 40 million. On the other hand, the Obama Plain is located in the central part of Japan and faces the Sea of Japan. And population density of the Obama Plain than that of the Kanto Plain. It is important to evaluate the energy potential of BHE in a part of this area for socio-economic studies. We have performed measurements of subsurface temperatures at 23 stations in the central part of the Kanto Plain (Saitama region). Subsurface temperatures and thermal conductivities at four stations at Obama Plain. In our presentation, we discuss that the difference of subsurface thermal environment and efficiency of BHEs.

Results of the numerical simulations show that the BHE efficiency increases by 20% when the subsurface temperature increases by 5 degC and the efficiency also increases by 30% when the groundwater flow varies from 0 m/year to 15 m/year.

In addition, the results of the subsurface temperature profiles show long-term subsurface warming in the Kanto plain during the last century. The influence of subsurface warming effects on the BHE efficiency through numerical simulations is discussed. We show that subsurface warming effects cause the BHE efficiency of heating to increase.

Keywords: Borehole Heat Exchanger system, groundwater, Kanto Plain, Obama Plain

Analysis of groundwater flow system for potential assessment of ground-source heat pump system in regional scale

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Ground-source heat pump system is an energy efficient and environment friendly technology that utilizes natural heat stored in a subsurface of shallow depth up to about 100m. It is used for space-heating, space-cooling, hot water supply and snow-melting purposes. Development rate of GSHP system is gradually increasing in Japan. However, the pace is still lacking behind America and European countries because of higher initial cost resulted by oversized design of ground heat exchangers (GHE) and lack of information on its advantages. To promote the development of GSHP system, evaluation of suitable locations for its installation is essential.

Regarding geology, Quaternary System usually exists in the shallow subsurface which mainly consists of sand and gravel. In this Quaternary System, groundwater is actively flowing. For this reason, hydrological and geological information are necessary because they largely influence the subsurface temperature distribution, and consequently affects heat exchange rate of GHE as well as overall operation of GSHP system.

In this study, groundwater flow system of the Tsugaru Plain in Aomori Prefecture was comprehended in order to assess the potentiality of GSHP system. A regional scale 3D groundwater flow & heat transport model was developed for this purpose. Horizontal dimensions of the model were 64km in east-west and 78km in north-south direction. In the model, layers 1 ~ 4 belonged to Quaternary System, layers 5 ~ 7 to Neogene and layers 8 ~ 12 to Paleogene. Saturated steady state simulation of groundwater flow and heat transport was conducted with this model. In Tsugaru Plain, hydrological field data such as groundwater level could not be measured as groundwater observation wells were not sufficient. Therefore, the analysis model was verified by comparing the computed hydraulic heads and water table with past studies and literature values. Additionally, computed results were validated by inspecting the path of simulated groundwater flow at natural springs, confirming if groundwater was flowing in upward direction.

Based on the simulation results of the analysis model, distribution maps of groundwater flow velocity, water table depth from subsurface and subsurface temperature were prepared using geographic information system (GIS). Groundwater flow velocity was found higher at peripheral areas. It can be due to higher hydraulic gradient near the mountainous areas. At areas with higher groundwater flow velocity, improved heat exchange rates of GHEs can be expected because of advection effect. Water table depth from surface was found to be shallow in most of the areas of the plain, which indicates the sustainable operation of GSHP system from the view point of groundwater availability and saturation of geological layers. Aomori Prefecture (2011) and Machida and Yasukawa (2008) showed similar results of water table. Subsurface temperature computed from heat transport simulation was found higher at the central area of plain, which is thought to be due to the heat transfer by groundwater advection. For space-heating with GSHP system, the central area can be suitable from temperature perspective. In this way, the comprehension of regional scale groundwater flow system accompanied with subsurface temperature distribution can provide useful information to assess suitable locations for the installation of GSHP system.

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Keywords: ground-source heat pump system, groundwater flow, heat transport, potential assessment