YOSHIMURA LAB.

[Climate system and Hydrology]

Department of Human and Social Systems

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Isotope hydrometeorology

Civil Engineering Department
Department of Natural Environmental Studies

How would Global Hydrological Cycle Change in Changing Climate??

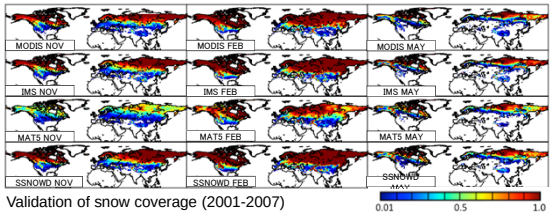
Water circulation on the earth, which is largely affected by Climate Change, influences human life. Thinking extensively about global hydrology, Yoshimura laboratory aims to clarify its mechanism and its relationship to climate system by various approaches, in order to contribute to our society. We especially focus on ① Development of land-surface/hydrological models that can be coupled with an earth system model, ② Evaluation and assessment of impact of Climate Change on hydrological environment and simulation of future climate, and ③ Clarification of the global hydrological process with stable water isotopes.

1. Development of land-surface/hydrological models that can be coupled with an earth system model

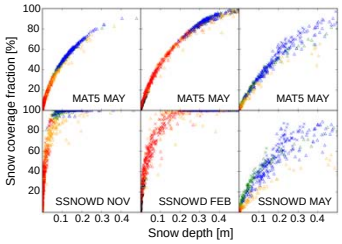
- Improvement of land surface models (ex. Offline version, snow accumulation processes and so on) in order to advance prediction of water resource
- Development of global river routine models which include floodplain inundation process. in order to calculate river discharge, depth, water surface area, storage

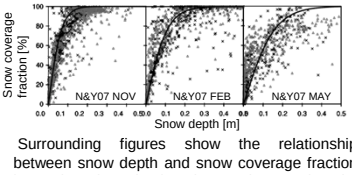
New snow covering model which includes heterogeneous snow accumulation in a grid cell

Introducing new snow accumulation model to land surface model improved reproduction of temporal-spatial variation of snow coverage. Moreover, we found that variation of snow cover has important impact on hydrological cycle on land surface.



Validation of snow coverage (2001-2007)

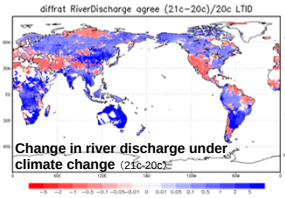


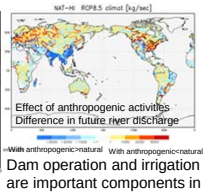


Surrounding figures show the relationship between snow depth and snow coverage fraction in major river basins in North America by observations (Niu and Yang, 2007; right) and simulations (MAT5 and SSNOWD; left).

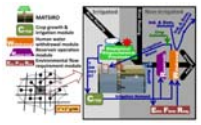
2. Evaluation and assessment of impact of Climate Change on hydrological environment

- Estimation of flood/draught risk and evaluation of its uncertainty
- Quantification of effect of anthropogenic activities (dam and irrigation) against flood risk

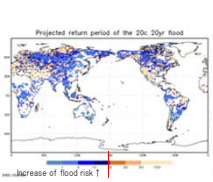




Dam operation and irrigation are important components in the present hydrology.

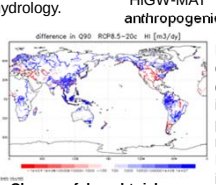


We coupled dam and irrigation modules with traditional land surface model. Our new model, "HiGW-MAT" can account for anthropogenic water operation.



Change of flood risk
(ex. Flood of 20yr return period)

Left map shows how flood risk (i.e., return period of 1/20 year in the 20C climate) will change in 21C. Blue indicates increase of the flood risk.



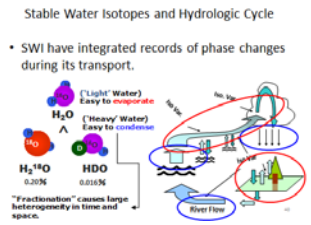
Change of draught risk

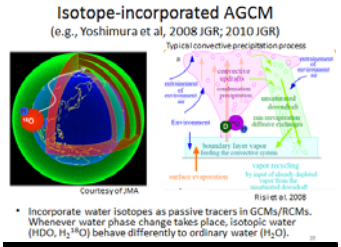
Left map shows change of draught risk index, Q90 (90 percentile of river discharge). Red indicates increase of draught risk.

3. Hydrological process study using stable water isotopes

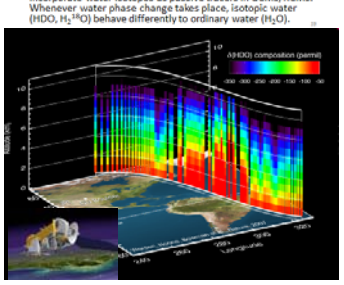
- Evaluation of paleo-climate reproduction using ^{18}O in coral leaves, ice cores, and trees and GCMs
- Mechanism of isotopic change in cloud formation process using cloud resolving model

As stable water isotopes ($H_2{}^{18}O$ and HDO) are distributed all over the world with great spatial and temporal variation, we can distinguish some water from the other. Due to their slightly different physical properties (saturation vapor pressure, and molecular diffusivity) from ordinary water ($H_2{}^{16}O$), water isotopes are thus redistributed between the vapor and condensed phases at each phase change. This redistribution is named "isotopic fractionation". As it depends on the physical conditions in which it occurs, the ratio of heavy and light isotopes in water constitutes a potential tracer of the hydrologic cycle and of past climate variations.

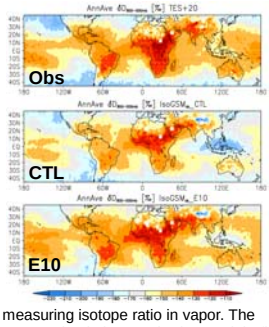




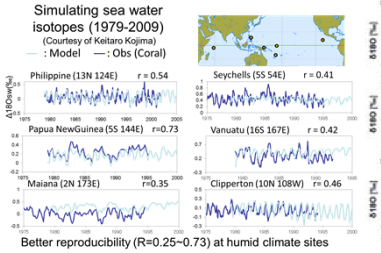
In our lab, we trace water in complex hydrological processes on the global scale by incorporating stable water isotopes into AGCM. Moreover, we analyze isotope ratio in precipitation, surface water and vapor sampled at various sites using mass spectrometer. We also use satellites and spectroscopies to observe spatial- and temporal variation of isotope in vapor.



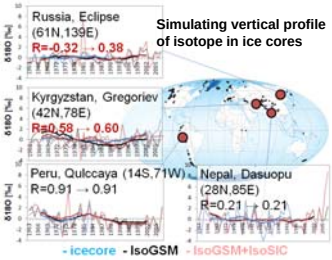
Worden et al. (2008), *Nature*



Upper left panels are the image of TES/AURA satellite measuring isotope ratio in vapor. The observation results are used to validate isotope enabled AGCM simulation results (upper right figs). They match well each other with the R value of 0.84.



Better reproducibility (R=0.25~0.73) at humid climate sites



Upper figures are the simulation results of isotope in coral leaves and ice cores using ocean- or snow-model forced with isotope enabled AGCM.