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ADAPTIVE RESERVOIR MANAGEMENT UNDER CLIMATE CHANGE IN THE LANCANG-MEKONG RIVER BASIN

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SS01-16: CHARACTERIZING HYDROLOGICAL RESPONSE IN A CHANGING ENVIRONMENT
SEPTEMBER 14, 2023

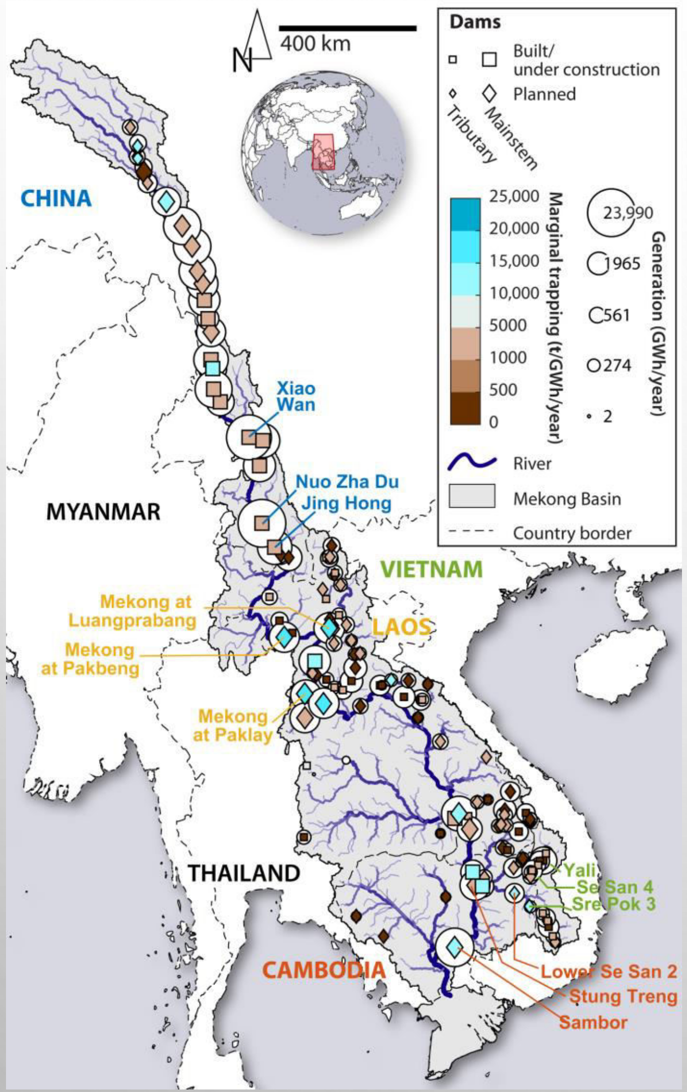
THE LANCANG-MEKONG RIVER BASIN

The Lancang-Mekong River Basin

River source of the Lancang River

Floating homes on the Mekong

HYDROPOWER POTENTIAL IN THE MEKONG



Battery of Southeast Asia:

The Mekong Basin has large potential for hydropower generation [268,000 gigawatt hours of electricity per year (GWh/year)], of which around half has been developed.

Schmitt et al. 2019

FLOOD IN MEKONG

Mekong flood along the border between Thailand and Laos. Photo taken by an astronaut aboard the International Space Station (ISS).

2 - Flooding Risk in the Lancang-Mekong River Basin under Global Change

from Part I - Water-Related Risks under Climate Change

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By Xiaobo Yun, Jie Wang, Huan Wu, Binod Baniya, Hui Lu, Siao Sun, Ximeng Xu, Xingcai Liu and Qiuhong Tang

In the future, this basin should experience a higher flood risk, with more flood events and a relative increase in the flood peak and frequency reaching up to +15 and +58 per cent, respectively.

DROUGHT IN MEKONG

Science

Mekong megadrought erodes food security

Vietnam hit with drinking water shortages and salt-ravaged rice paddies

6 APR 2016 · BY CHRISTINA LARSON

The lower Mekong river basin has been experiencing severe drought hazards with serious economic losses.

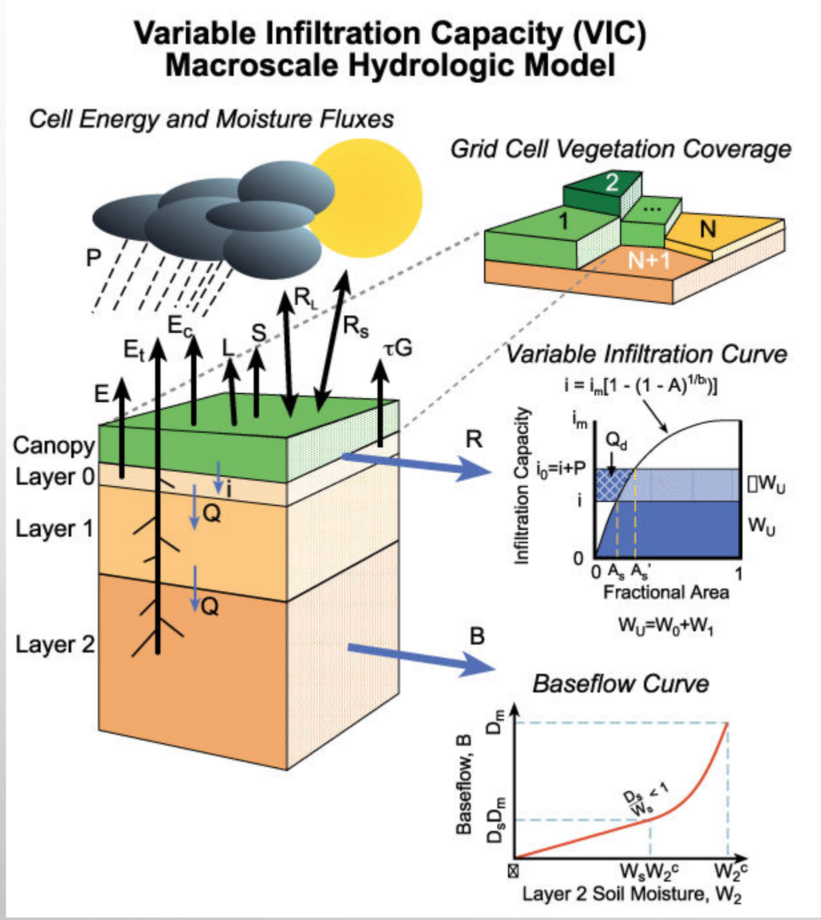
With different climate scenarios, the lower Mekong river basin is likely to see more severe droughts in the next 30, 60, and 90 years due to less precipitation, high air temperature, and high evaporation.

BUILD RESILIENCE TO CLIMATE CHANGE

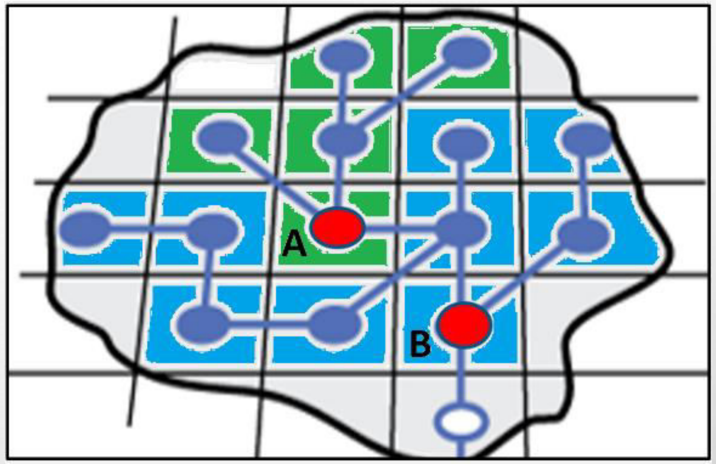
- **Reservoirs are playing an important role in clean energy (Goal 7 SDG), and flood and drought (Goals 11 and 13 SDG) mitigation in the Lancang-Mekong river basin.**

- **Can the reservoirs be managed to mitigate future water hazards from climate change? And at what cost?**

THE VIC-R MODEL WITH RESERVOIR IMPACTS



The VIC model (Liang et al., 1994) is a large-scale, semi-distributed hydrologic model.



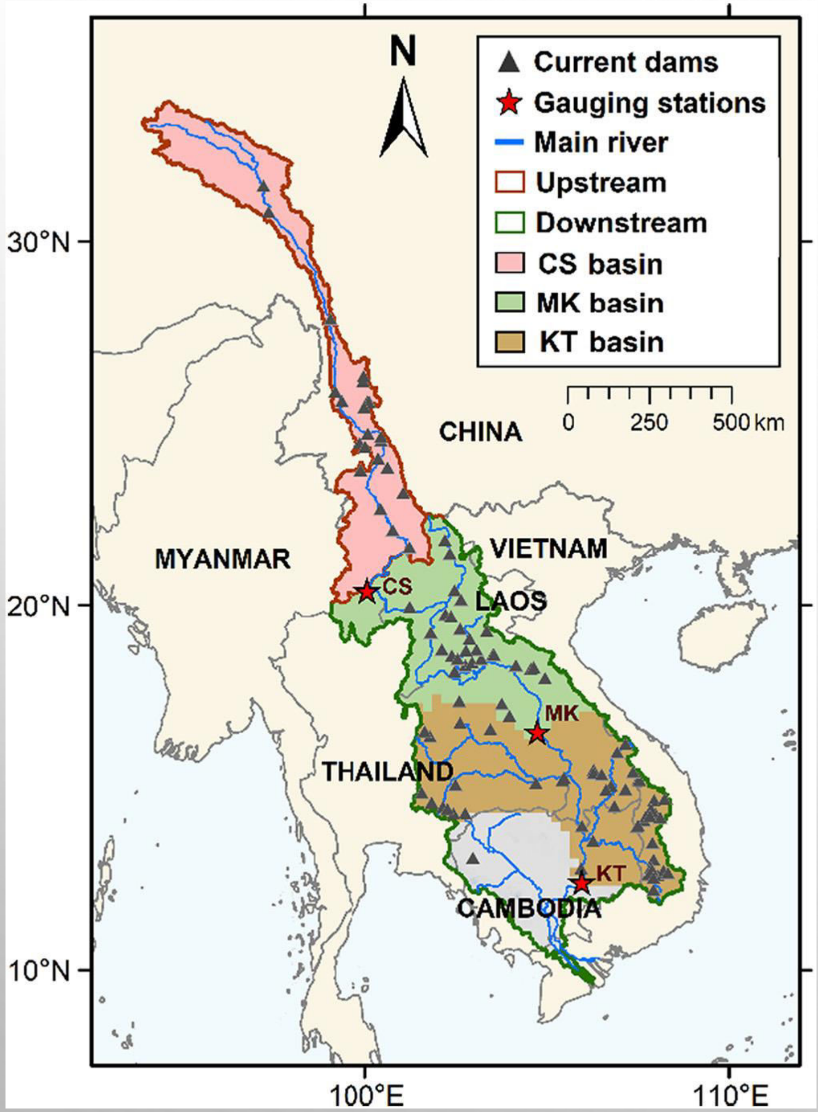
The routing model with reservoirs (the red dots).

RESERVOIR OPERATION STRATEGIES

- **To assess the reservoir impact, an advanced Standard Operation Policy type 2 (SOP2) (Wang et al., 2017a) model was incorporated into the VIC model.**
- **The model assumes reservoirs mainly to operate for flood control along with the environmental protection and power generation.**
- **A number of reservoir operation strategies are considered, that is, prioritizing hydropower generation (maintain a relatively high hydraulic water head to improve power generation), prioritizing flood control (maintain a relatively low hydraulic water head for incoming flood during wet season), and compromising strategies.**

Yun et al. 2021, 2022

MODEL SETTING



The hydrological processes are simulated at daily time scale with a 0.25° spatial resolution.

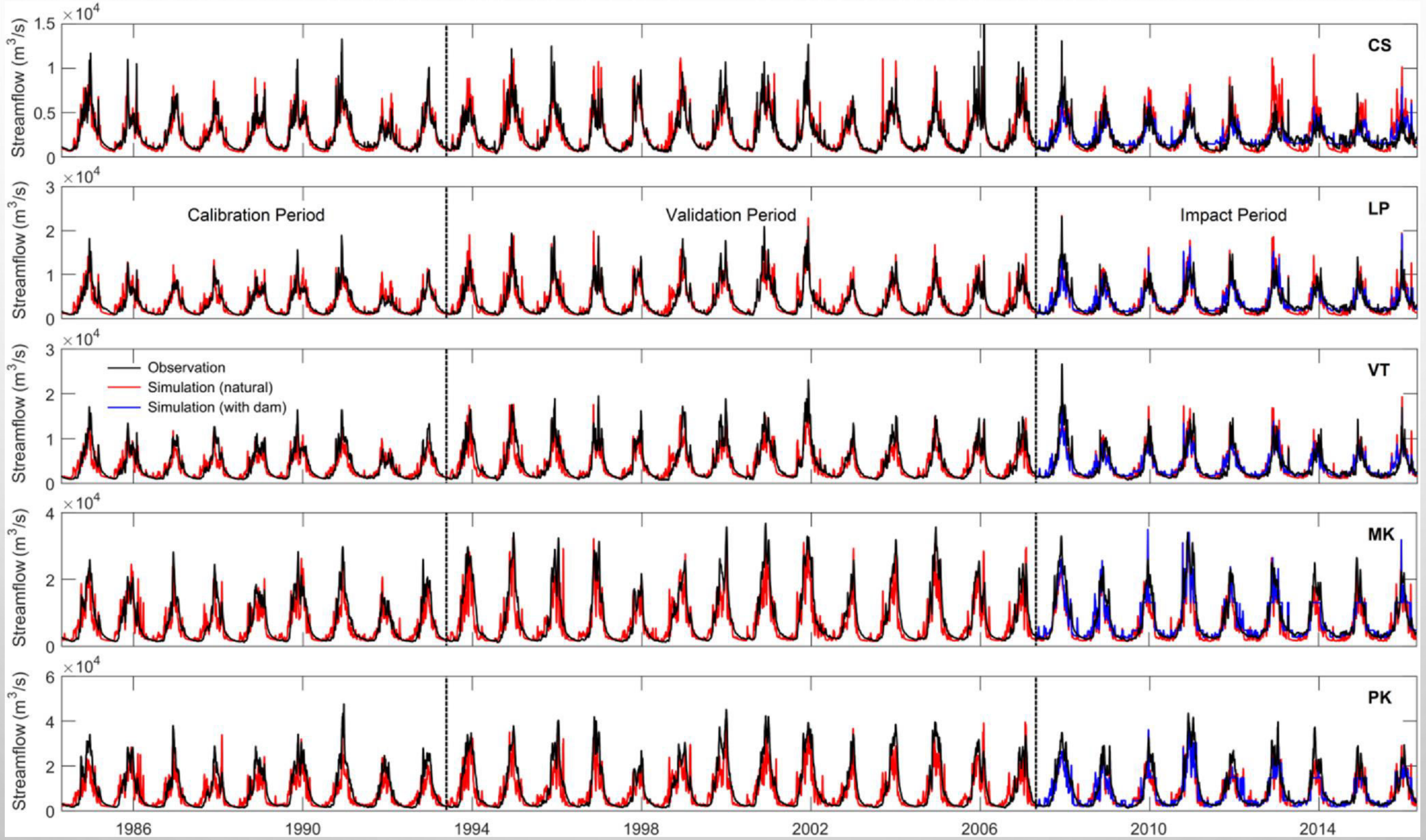
103 reservoirs are considered in the Lancang-Mekong river basin.

Future climate forcing data were provided by the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP3b). The bias-corrected CMIP6 climate forcings contain five GCMs for three scenarios (SSP126, SSP370, SSP585)

Chiang Sean (CS) basin:
upstream
Mukdahan (MK)
Kratie (KT) basin: downstream

Yun et al. 2021

MODEL VALIDATION



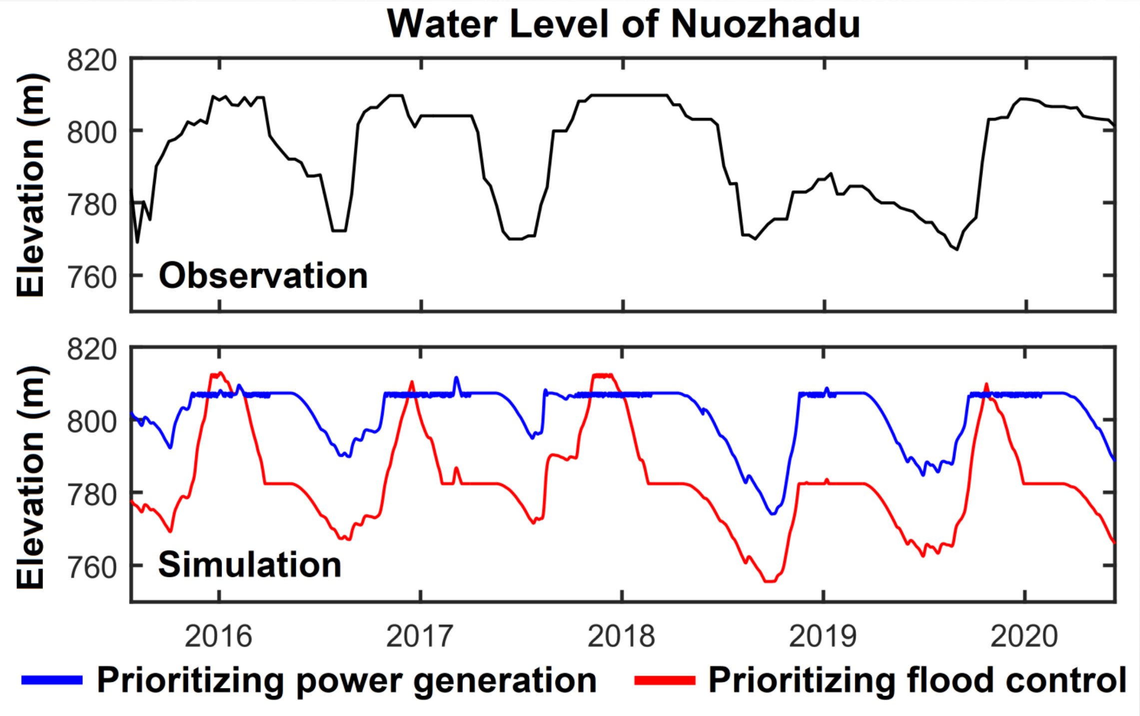
Nash–Sutcliffe Efficiency (NSE): 0.69-0.76

NSE of natural simulations: -0.13

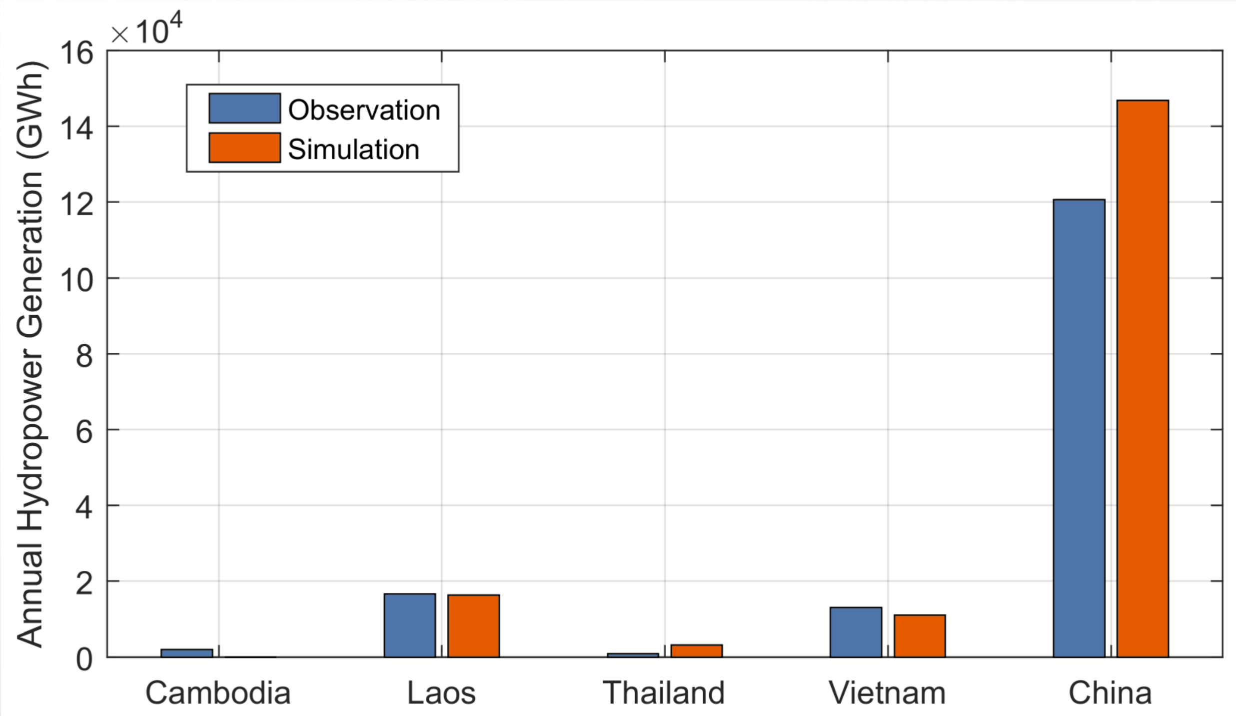
NSE of simulation with dams: 0.61-0.75

Yun et al. 2020

PERFORMANCE OF RESERVOIR SIMULATIONS



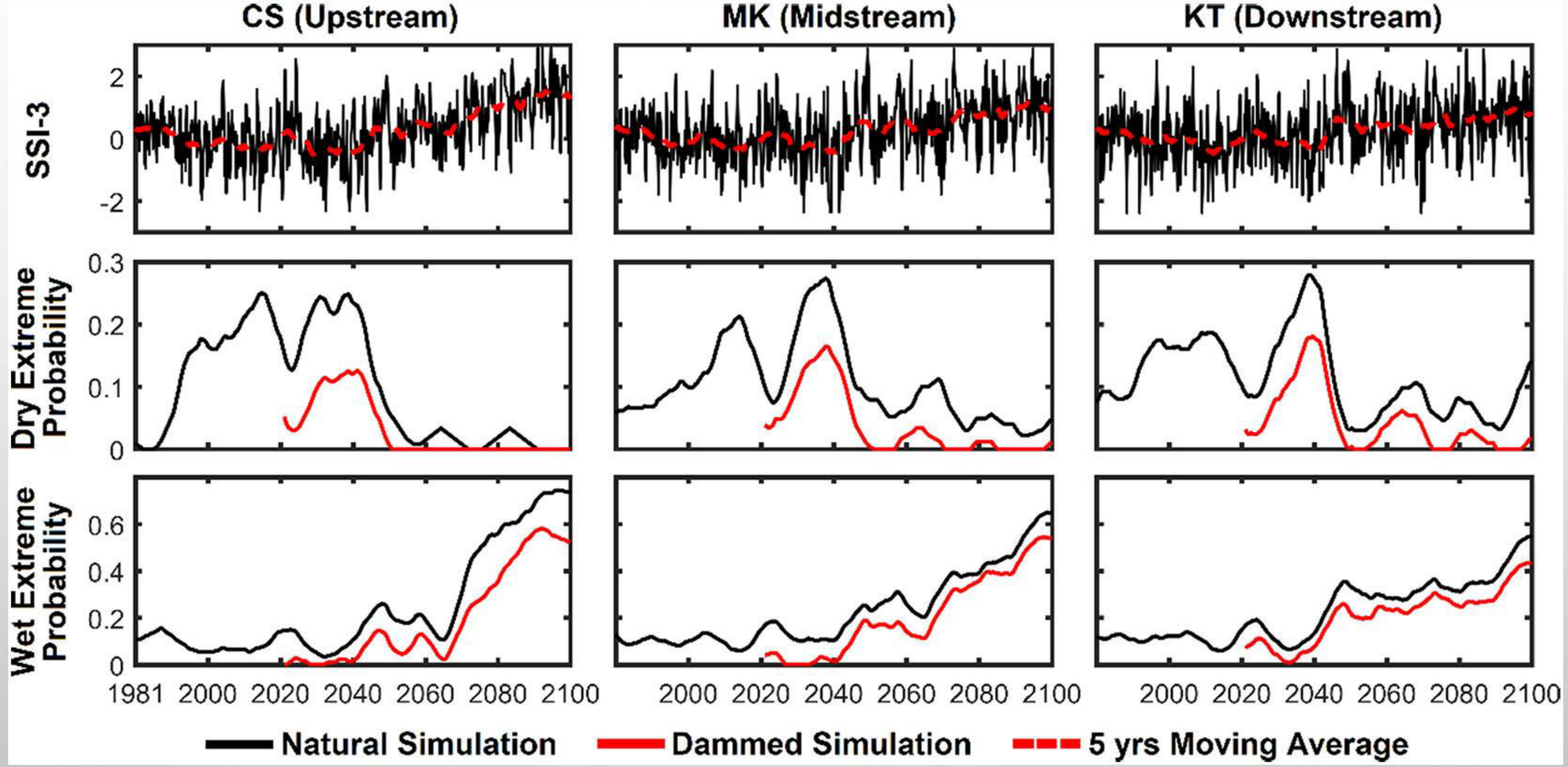
Comparison of observed and simulated water level at a reservoir in the Lancang river basin



Comparison of observed and simulated hydropower generation at Lancang-Mekong countries

Yun et al. 2022

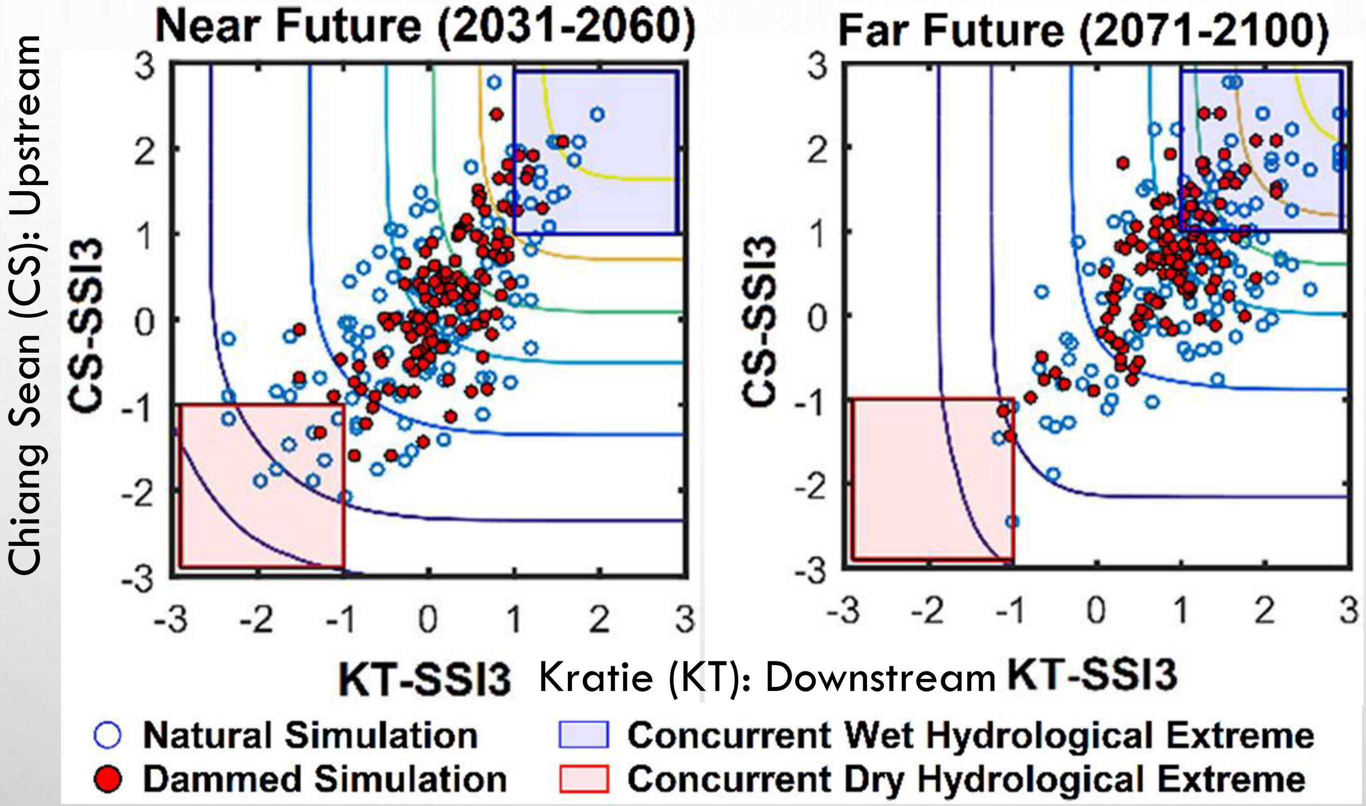
RESULTS: FUTURE HYDROLOGIC EXTREMES



Standardized Streamflow Index (SSI-3), dry extreme probability, and wet extreme probability at the three stations during 1981–2100 under SSP585 scenario

Yun et al. 2021

RESULTS: BASIN-WIDE EXTREME EVENTS

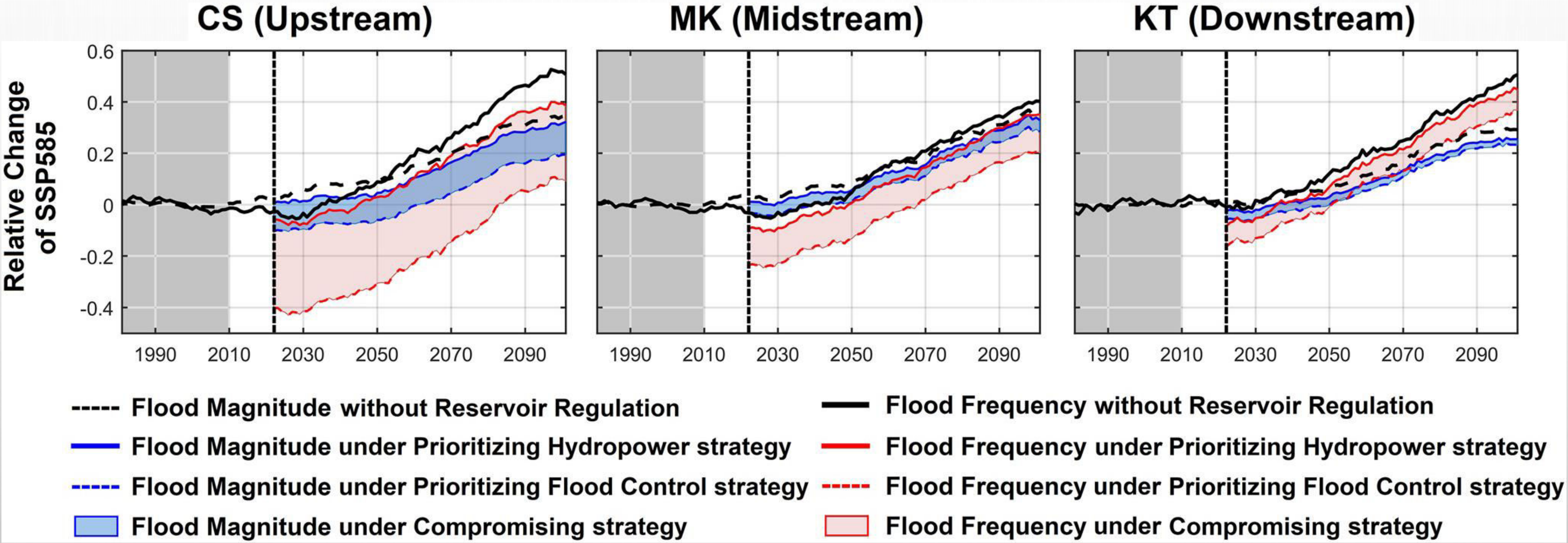


Level curve of the joint probability distribution of the SSI-3 at upstream and downstream stations under SSP585 scenario

Reservoir regulation can mitigate the basin-wide dry extreme events by 100% and the wet extreme events by 32%.

Yun et al. 2021

RESULTS: CHANGE OF FLOOD WITH RESERVOIRS

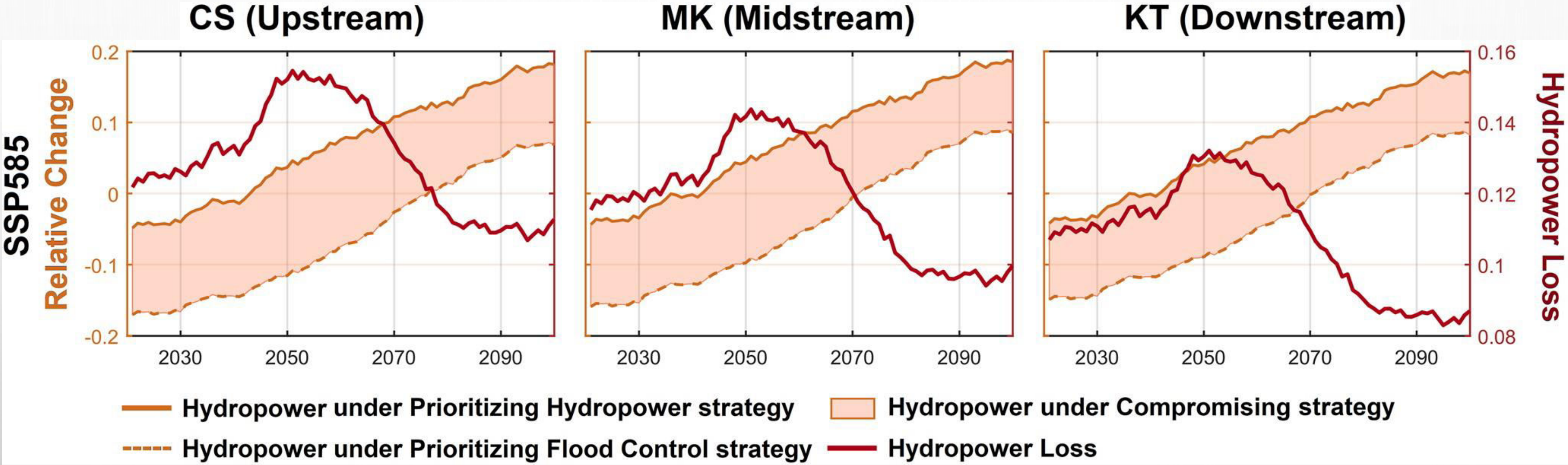


The 30-year moving average relative changes of flood magnitude and flood frequency with respect to the baseline period during 1980–2009

Adaptive reservoir operation can reduce flood magnitude by 5.6%–6.4% and reduce flood frequency by 17.1%–18.9%.

Yun et al. 2022

RESULTS: IMPACTS ON HYDROPOWER

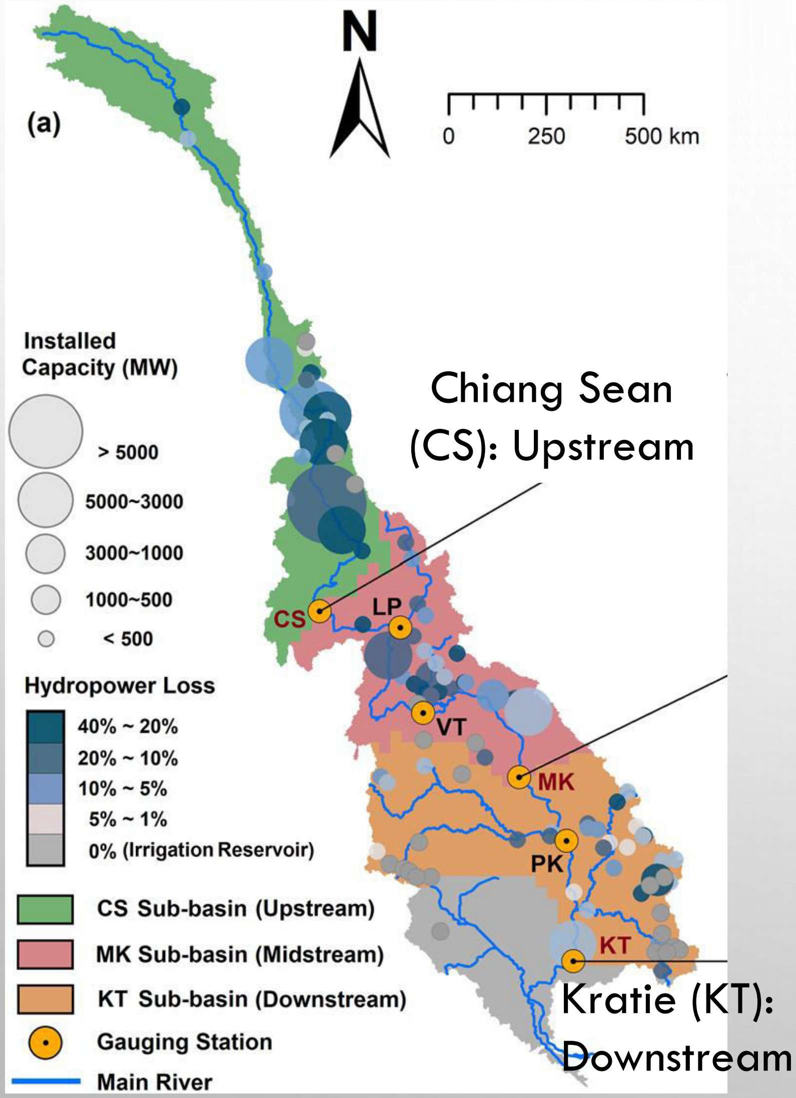


The 30-year moving average relative changes of hydropower generation with respect to the baseline period during 1980–2009. The hydropower loss is defined as the difference of hydropower generation using the two reservoir operation strategies compared to the baseline period.

Adaptive reservoir operation reduces flood at the cost of 9.8%–14.4% of basin-wide hydropower generation.

Yun et al. 2022

RESULTS: IMPACTS ON HYDROPOWER



Yun et al. 2022

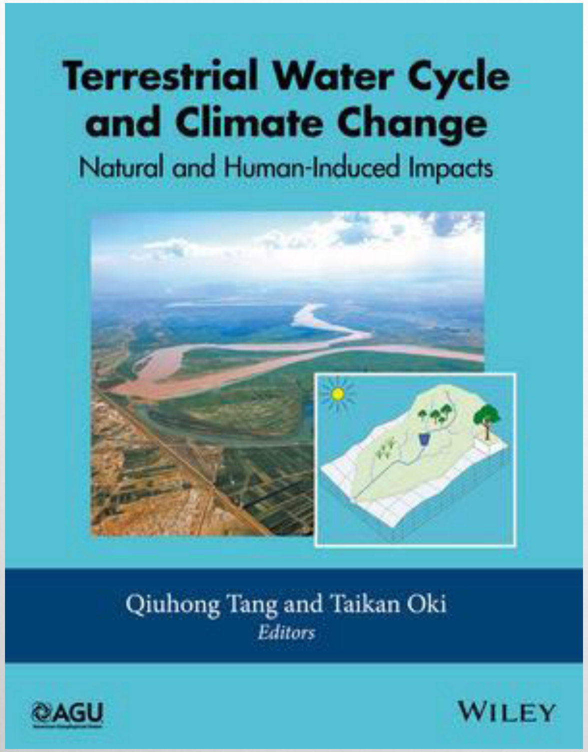
If managed properly, reservoirs at the upstream can play an important role in reducing the flooding at the downstream.

Upstream reservoirs suffer more hydropower loss (5.4 times) than downstream ones when flood control is prioritized in reservoir regulation.

TAKE HOME MESSAGE

- A reservoir module was incorporated into the Variable Infiltration Capacity (VIC) hydrological model to simulate the streamflow susceptible to the reservoirs in the Lancang-Mekong river basin.
- Reservoirs can be managed to mitigate the risks of hydrological extreme events, and help achieve Goals 11 and 13 SDG in the river basin.
- Adaptive reservoir regulation comes with a cost of hydropower generation, suggesting the importance of coordinating water and energy management across countries in the transboundary river basin.

THANK YOU


Terrestrial Water Cycle and Climate Change
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Qiuhong Tang and Taikan Oki
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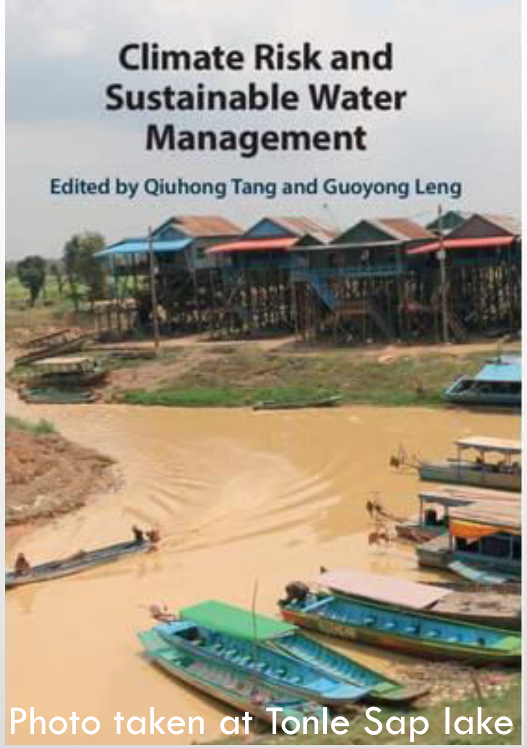
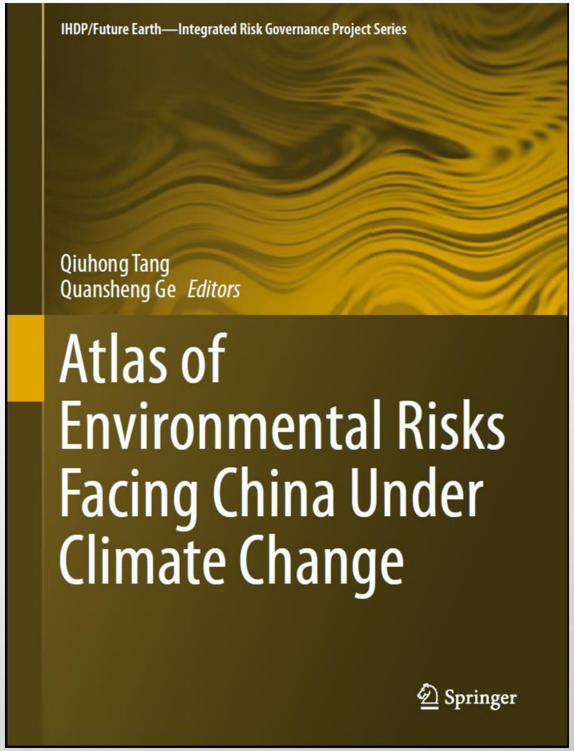

Climate Risk and Sustainable Water Management
Edited by Qiuhong Tang and Guoyong Leng
Photo taken at Tonle Sap lake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