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Project Title:
Climate Change and Water Resources in Great Rivers Region in Southeast and South Asia

Principal Investigator:
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Southern University of Science and Technology
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Institute of Atmospheric Physics, CAS
Institute of Geographic Sciences and Natural Resources Research, CAS
Beijing Normal University
University of Gothenburg

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March 2018 – February 2023

"Climate Change and Water Resources in Great Rivers Region in Southeast and South Asia"

Project Office

NEWS

27 January

Professor Deliang CHEN appointed Editorial Board member of the "10 New Insights in Climate Science 2021"

Prof. **Deliang CHEN** has been appointed Editorial Board member of the "10 New Insights in Climate Science 2021" led by the Future Earth, the Earth League and WCRP.

Each year the Future Earth, the Earth League and WCRP consult researchers and carry out a horizon scan in fields related to climate change on what the latest findings and most important new emerging fields are. They summarize this in 10 important scientific insights, and the result has always been a rich and valuable scientific synthesis for policy and society at large, a testament to the ever-expanding and improving knowledge of our planetary climate systems and the interactions with the human world.

Full report link: https://10nics2020.futureearth.org

01 February

Professor Deliang CHEN awarded the H.M. The King's Medal in the 8th size

Prof. **Deliang CHEN** was awarded the H.M. The King's Medal in the 8th size with the Order of the Seraphim ribbon for outstanding contributions to Swedish and international climate research.
Prof. Deliang CHEN is internationally known for his extensive climate research and for his commitment to bringing climate research to society. For example, he is the coordinating lead author of the forthcoming IPCC report.
Prof. Deliang CHEN's most important field of research is about the development of a new approach to describe atmospheric circulations. The research provides an improved understanding of climate change and its effect on air pollution, marine ecosystems, sea level and sea ice in and around Sweden.

"It is a great honor, and I am delighted about receiving this medal. I would also like to take this opportunity to say that I am grateful for the support of the leaderships of Gothenburg University for my international commitment," says Prof. Deliang CHEN.

Globally observed trends in mean and extreme river flow attributed to climate change

Recently, Prof. **Junguo LIU** from the Southern University of Science and Technology (SUSTech) joined an international research team including scientists from ETH Zurich (Switzerland) and 17 other institutes, published a paper entitled "Globally observed trends in mean and extreme river flow attributed to climate change". The paper was published in **Science**.
River flow has changed significantly worldwide in recent decades and this research team has now demonstrated that it is climate change, rather than water and land management, that plays a crucial role at a global level.

Climate change is affecting the water balance of our planet. Depending on the region and the time of year, this can influence the amount of water in rivers potentially resulting in more flooding or drought. River flow is an important indicator of water resources available to humans and the environment. The amount of available water also depends on further factors, such as direct interventions in the water cycle or land-use change.

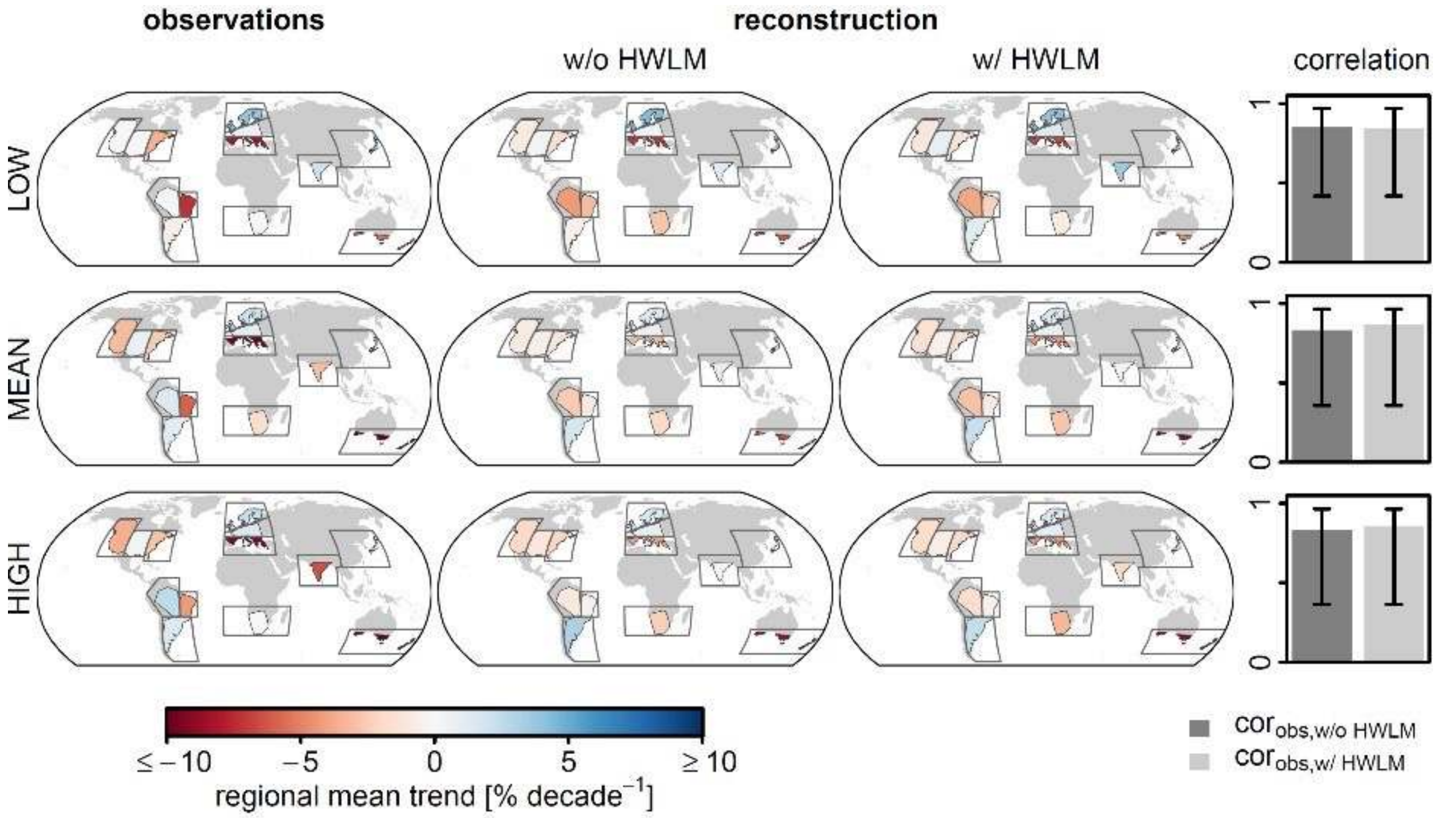


Figure 1: Comparison of observed and reconstructed regional median river flow trends (1971–2010)

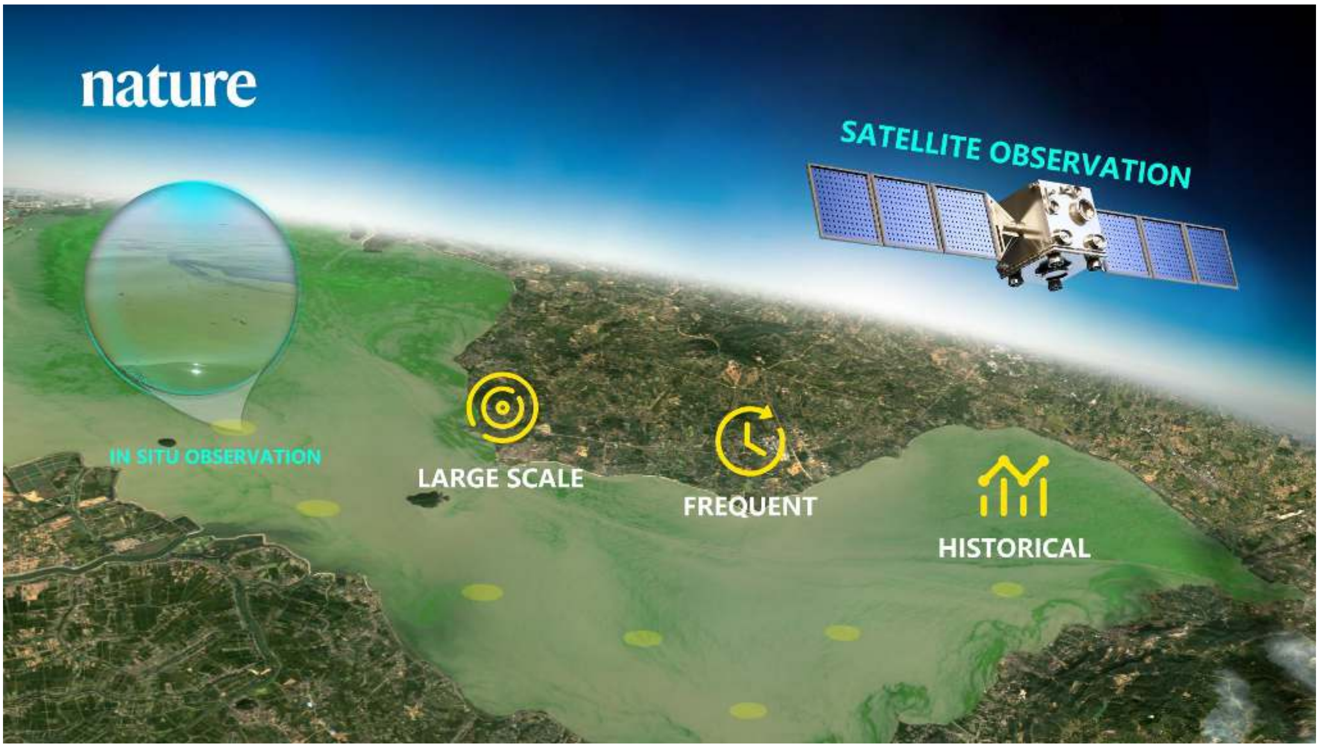
For example, if the water is diverted for irrigation or regulated via reservoirs or forests are cleared and monocultures have grown in their place, this can have an impact on river flow. However, how river flow has changed worldwide in recent years was so far not investigated using direct observations. Similarly, the question of whether globally visible changes are attributable to climate change or to water and land management had not been clarified.

Now, the international research team has succeeded in breaking down the influence of these factors after analyzing data from 7250 measuring stations worldwide. The study demonstrates that river flow changed systematically between 1971 and 2010. Complex patterns were revealed; some regions such as the Mediterranean and north-eastern Brazil had become drier, while elsewhere the volume of water had increased, such as in Scandinavia.

The results were published in **Science**
Full article link: https://science.sciencemag.org/content/371/6534/1159

Concerns about phytoplankton bloom trends in global lakes

Scientists from the Southern University of Science and Technology (SUSTech), **Lian FENG**, **Junguo LIU**, **Chunmiao ZHENG** and other colleagues, published a paper entitled “Concerns about phytoplankton bloom trends in global lakes” in **Nature**. This paper questions the results of the paper published in Nature by a collaborated team from Stanford University and NASA (Ho et al., 2019). Ho et al. (2019) used remote sensing satellite images to track the long-term changes of algal bloom in 71 lakes worldwide and concluded that the eutrophication of global lakes is increasing. However, Lian Feng’s team proved their results by using theoretical analysis and solid evidence, and their Matters Arising article has been published in Nature.



The paper pointed out that Ho et al. (2019) has the following problems:

1. Ho et al. (2019) used a single near-infrared band to quantify lake blooms, where the Bloom strength tends to be substantially overestimated in sediment-rich waters.
2. Ho et al. (2019) used the Fmask algorithm to determine lake surface area could lead to substantial underestimations of bloom severity.
3. Ho et al. (2019) did not consider the impacts of atmospheric radiance on the satellite signal.

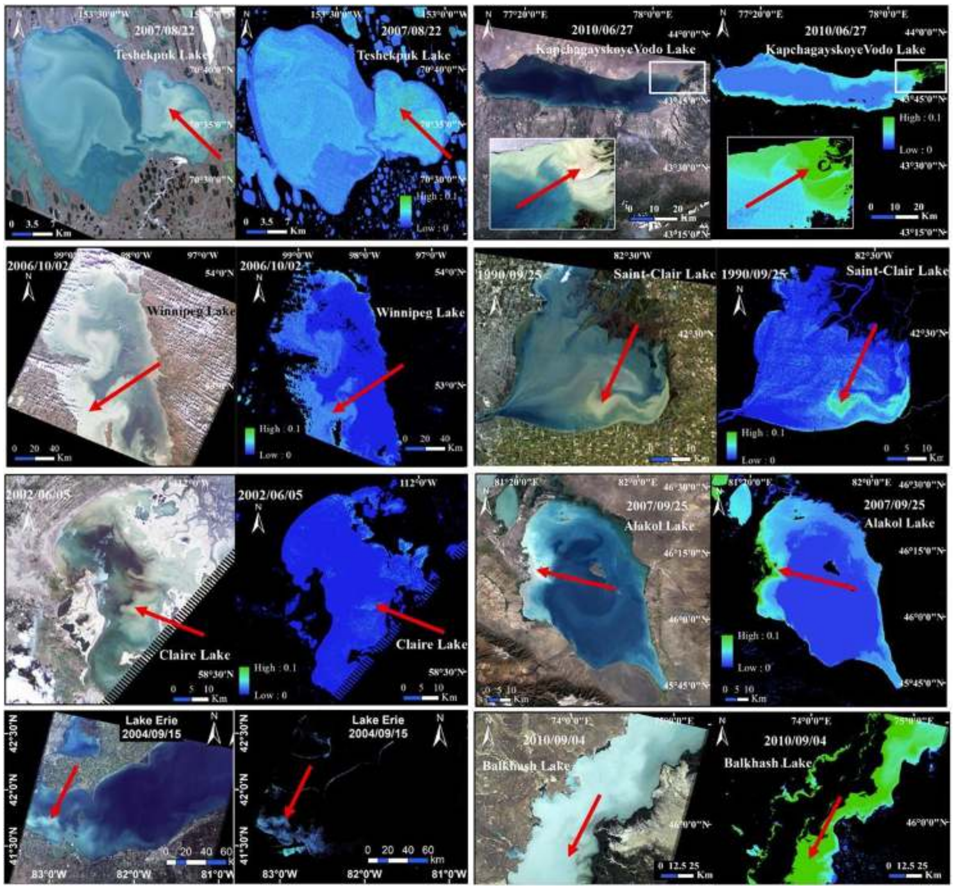


Figure 1: Examples showing the effects of high sediment loads on the bloom intensity calculations in eight of the lakes studied in Ho et al., 2019

The results were published in **Nature**

Full article link: https://www.nature.com/articles/s41586-021-03254-3

Regionalization of Seasonal Precipitation over the Tibetan Plateau and Associated Large-Scale Atmospheric Systems

Precipitation over the Tibetan Plateau (TP) has major societal impacts in South and East Asia, but its spatiotemporal variations are not well understood, mainly because of the sparsely distributed in situ observation sites. Led by PhD student **Hui-Wen LAI**, Prof. **Deliang CHEN**'s group from Department of Earth Sciences at University of Gothenburg, Sweden, conducted a study on the regionalization of seasonal precipitation over the TP and associated large-scale atmospheric systems, with the help of the Global Precipitation Measurement satellite product IMERG and the ERA5 dataset from 2000 to 2019.

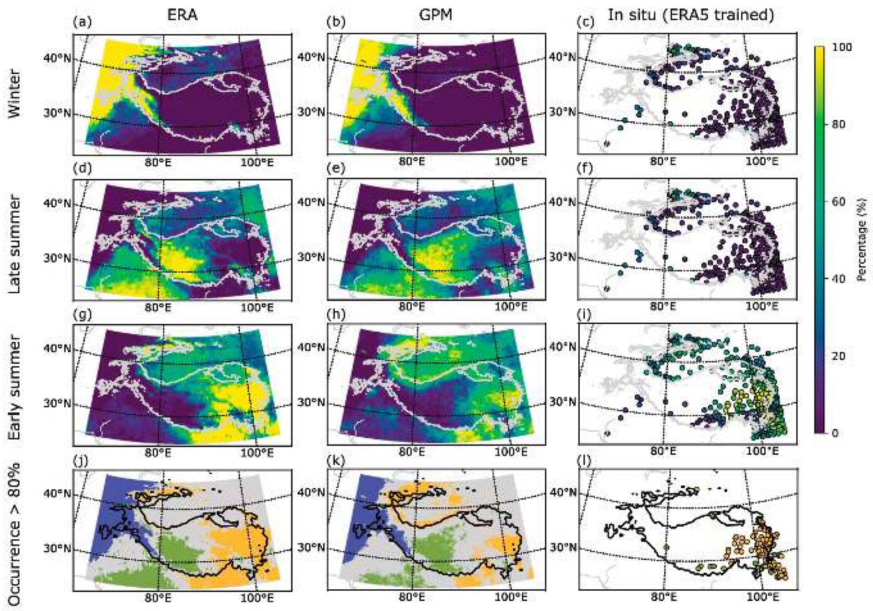


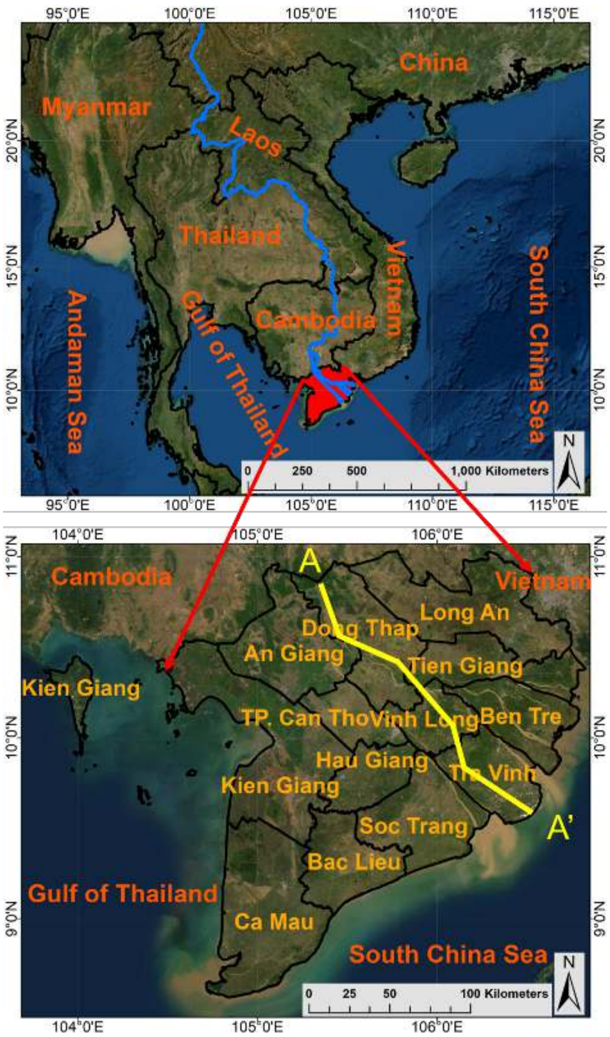
Figure: Frequency of occurrences of precipitation regimes during June 2000 to May 2019 from (left) ERA5 and (middle) GPM, as well as (right) during June 2000 to May 2018 from in situ observation with ERA5-trained SOM for the (a)–(c) winter peak regime, (d)–(f) late summer peak regime, and (g)–(i) early summer peak regime. Areas with a frequency of occurrences larger than 80% are shaded by the color of the main cluster for (j) ERA5, (k) GPM, and (l) in situ observations.

The classification reveals three main precipitation regimes with distinct seasonality of precipitation: the winter peak, centered at the western plateau; the early summer peak, found on the eastern plateau; and the late summer peak, mainly located on the southwestern plateau. On a year-to-year basis, the winter peak regime is relatively robust, whereas the early summer and late summer peak regimes tend to shift mainly between the central and northern TP but are robust in the eastern and southwestern TP. A composite analysis shows that the winter peak regime experiences larger amounts of precipitation in winter and early spring when the westerly jet is anomalously strong to the north of the TP. Precipitation variations in the late summer peak regime are associated with intensity changes in the South Asian high and Indian summer monsoon. The precipitation in the early summer peak regime is correlated with the Indian summer monsoon together with anticyclonic circulation over the western North Pacific. The results provide a basic understanding of precipitation seasonality variations over the TP and associated large-scale conditions.

The results were published in **Journal of Climate**.
Full article link: https://journals.ametsoc.org/view/journals/clim/34/7/JCLI-D-20-0521.1.xml

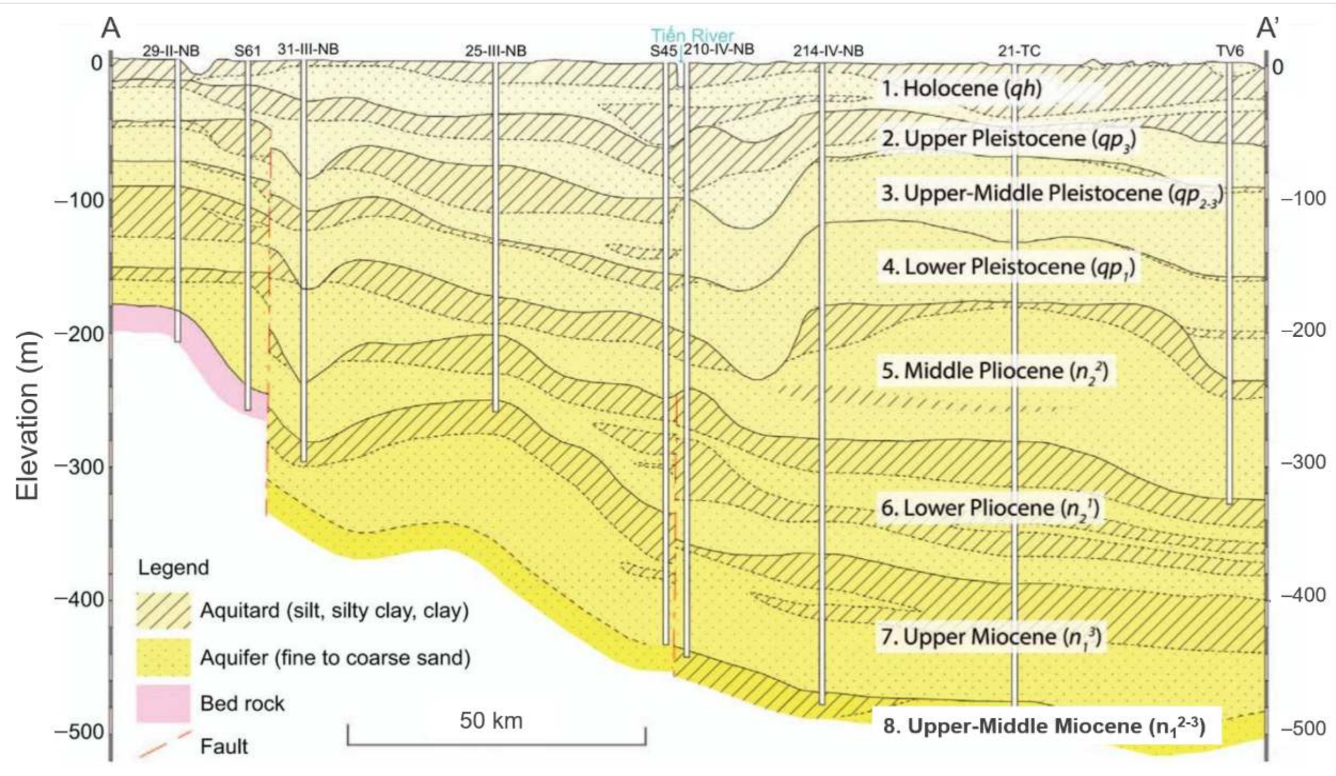
Research

Saltwater intrusion: An enormous threat to groundwater security in the Mekong Delta in southeast Asia under global change



With a continuous upward trend in temperatures and sea levels globally, the Mekong Delta located at the mouth of the lower reach of the Mekong River basin in southeast Asia (bounded by the South China Sea to the east and south, the Gulf of Thailand to the west, and the Cambodian border to the north) is experiencing rising susceptibility to flooding, water pollution, and loss of aquatic biodiversity. Since surface water is encountering severe problems of saltwater intrusion especially during the dry season from November to April, groundwater plays a key role in sustaining the communities and economies in populated cities and rural areas devoid of other reliable freshwater sources in the Mekong Delta. Due to the rapid development of agriculture, aquaculture, and manufacture since the 1990s, exponentially increasing freshwater demand for domestic use, upland crops irrigation, aquacultural use, and industrial purposes has led to extensive groundwater utilization, resulting in numerous problems such as groundwater depletion, land subsidence and saltwater intrusion.

Recently, the issue of saltwater intrusion into groundwater systems in the Mekong Delta under the impacts of human activities and climate change has been recognized as one of the primary geo-hazards which poses a great threat to groundwater security. Previous research indicated that groundwater over-exploitation and relative sea-level rise can cause saltwater intrusion into both shallow groundwater systems (*qh* aquifer) and deep groundwater systems (qp_3, qp_{2-3}, qp_1, n_2^2, n_2^1, n_1^3, and n_1^{2-3} aquifers), while storm surge, changing precipitation and temperature regimes, uncontrolled drainage canals, operation of hydropower dams, and rapid development of aquaculture mainly cause saltwater intrusion into shallow groundwater systems (*qh* aquifer) and the upper portion of deep groundwater systems (qp_3 and qp_{2-3} aquifers). So far, theoretical studies, data analyses, laboratory tests, field investigations, as well as engineering measures have been initialized for monitoring and controlling saltwater intrusion into groundwater systems in the Mekong Delta.



However, existing knowledge gaps and challenges greatly limit the development of saltwater intrusion research, including: 1) spatial variation of permeability and thickness of the silt and clay aquitard as well as locations and dimensions of existing hydraulic windows breaching the silt and clay aquitard; 2) present-day highly heterogeneous 3D distribution of saline groundwater zones; 3) future 3D distribution of saline groundwater zones; and 4) most effective and economical control measure to mitigate saltwater intrusion. To bridge these gaps, future work should: 1) apply environmental isotope techniques in combination with borehole tests to gain detailed hydrogeological information; 2) maintain regular groundwater monitoring and collect groundwater samples from multiple hydro-stratigraphic units at different depths for water quality analysis; 3) develop a series of variable-density groundwater flow and salt transport models representing various scenarios of human activities and climate change for predicting future extent of saltwater intrusion; and 4) identify the dominant factor causing saltwater intrusion and determine the most effective and economical engineering technique to address saltwater intrusion problems in the Mekong Delta.

The review, which was co-authored by Prof. **Qiuhong TANG** at Institute of Geographic Sciences and Natural Resources Research, CAS, and Prof. **Deliang CHEN**, member of the TPE executive committee and August Rohss Chair at the University of Gothenburg (Sweden), identified major knowledge gaps and challenges regarding saltwater intrusion and the subsequent groundwater quality degradation under the impacts of human activities and climate change in the Mekong Delta. The paper is in press at **Advances in Climate Change Research**.

Undermined co-benefits of hydropower and irrigation under climate change

Hydropower, as renewable and climate-friendly energy, makes substantial contributions to meet ascending global power demands, accounting for 73% of global renewable power supply. Dam construction is mostly aimed for multiple functions, including irrigation water provision, hydropower, and some others that bring substantial social benefits. However, global warming impacts on the interaction of the positive outcomes of damming remain little known, particularly in terms of the sustainability of their co-benefits, whereby investigating the different impacts of global warming scenarios of 1.5°C and 2°C has been a hotspot in water resources and energy research worldwide.

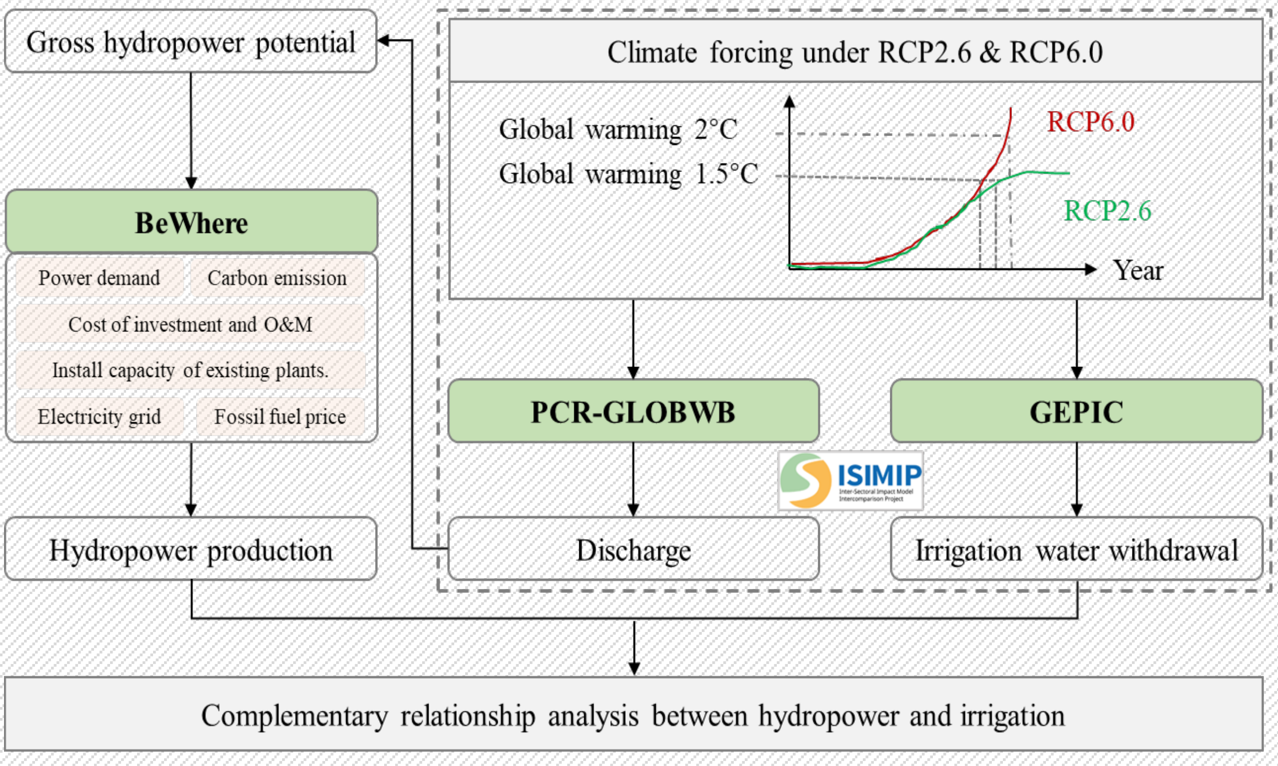


Figure 1: The schematic of the complementary relation analysis framework

Recently, Prof. **Junguo LIU**'s group used an integrative analysis based on a hydrological, techno-economic and agricultural modeling framework to evaluate the effects of global warming scenarios of 1.5°C and 2°C on the co-benefits between hydropower and irrigation in the Mekong River basin. The results show the declined hydropower generation and irrigation water supply in the Mekong River basin under 1.5°C and 2°C warming scenarios. The co-benefits between the hydropower and the irrigation is more undermined by the global warming of 2℃ relative to 1.5℃ in the Mekong River basin. Moreover, the changes of co-benefits are sensitive to the consideration of the protected areas in the basin. With the consideration of the protected areas, the co-benefits would be enhanced by 2℃ global warming compared to 1.5℃ global warming. Therefore, it is critical for decision-makers to consider the tradeoffs between the environment and dam construction for ensuring energy and food security under global warming scenarios.

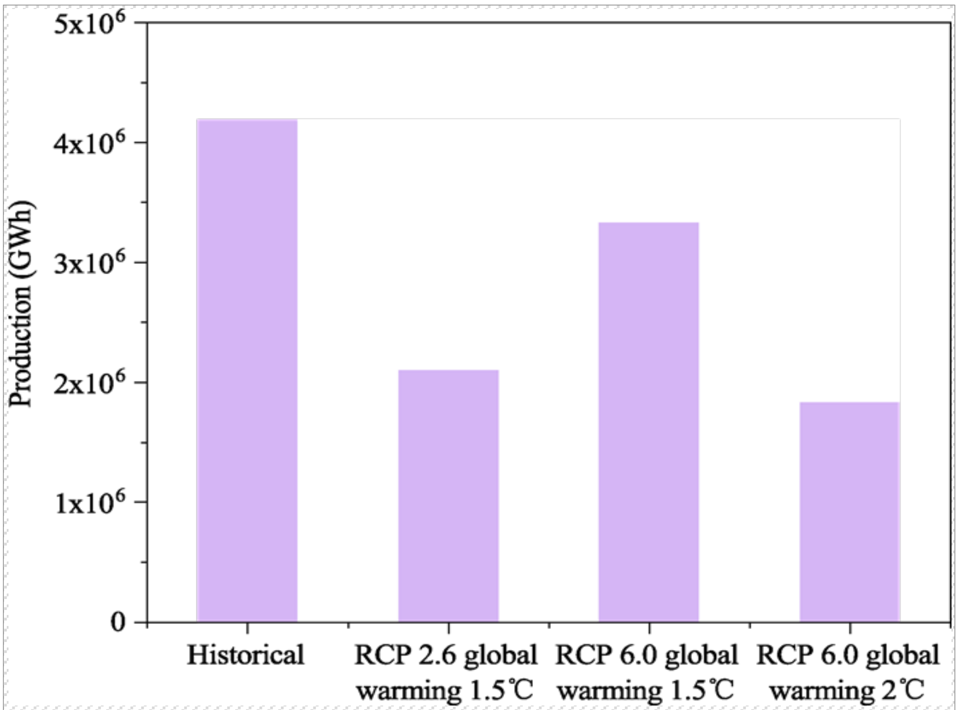


Figure 2: Hydropower production at the historical period and different scenarios of global warming.

The study results could provide support of selecting optimal sites for hydropower plants under 1.5°C and 2°C global warming. Moreover, this research would facilitate building a basis for decision-makers on water, energy, and food security under 1.5°C and 2°C global warming. The understanding of the water-energy-food nexus could help to achieve the Sustainable Development Goals (SDGs) such as Goal 2 “Zero hunger” and Goal 7 “Affordable and clean energy”.

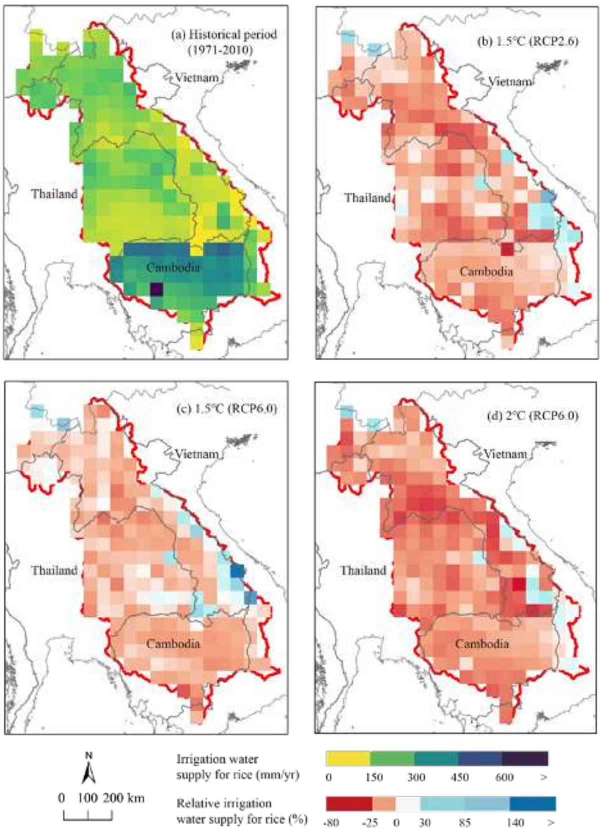


Figure 3: Annual mean irrigation water supply for rice (mm per growing season) (1970-2010), and the differences in the annual mean irrigation water supply for rice between historical period and the global warming scenarios of 1.5℃ and 2℃.

The results were published in **Resources, Conservation and Recycling**.

Full article link: https://www.sciencedirect.com/science/article/pii/S092134492030690X

Research

Undermined co-benefits of hydropower and irrigation under climate change

Food, energy, and water (FEW) resources are critical concerns to achieve the United Nations 2030 Sustainable Development Goals. However, there is still insufficient understanding of the FEW Nexus especially a comprehensive understanding of the impacts of both climate change and socio-economic development. The main difficulties are to develop scenarios considering combined impacts in the future and to quantify the interconnections of food, energy, and water systems. The Mekong River Delta (in Vietnam) was chosen as a case study due to its growing challenges from climate change and socio-economic development.

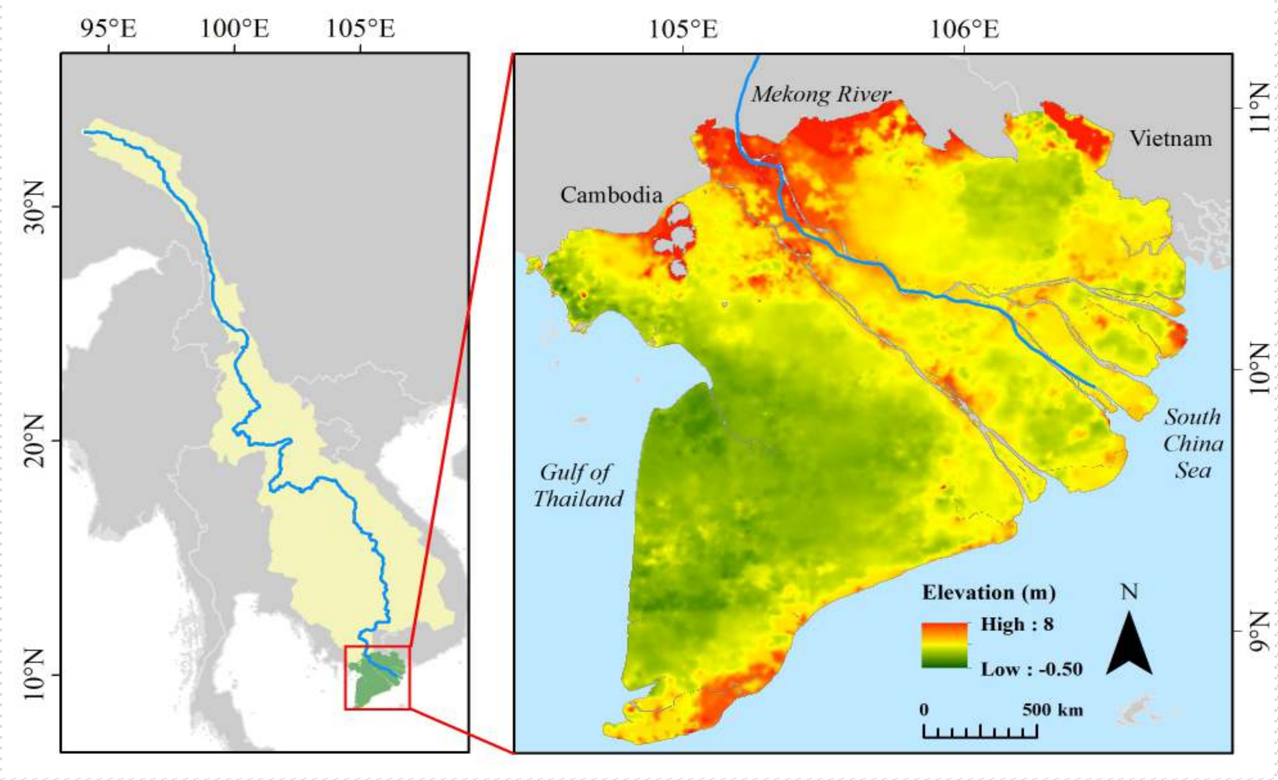


Figure 1. The Mekong River Delta

Prof. **Junguo LIU**'s group adopted an integrated water resources management model to simulate the regional rice production, power generation, and water demands under various scenarios from the Coupled Model Intercomparison Project Phase 6 that consider both climate change and socio-economic pathways. The study results showed that rice yields were vulnerable to climate changes due to the increasing extreme events such as floods and droughts. Power generation was projected to increase due to the growth of GDP and the population of all five scenarios. For example, the power generation in 2050 of SSP5-8.5 will be about 10 times of the 2010's generation as the scenario is energy and resource-intensive. Further, the average total water withdrawal in 2050 was estimated to increase by 40% compared to that in the 2016 drought year and will be more than 3 times higher than the average withdrawal of 1995–2010.

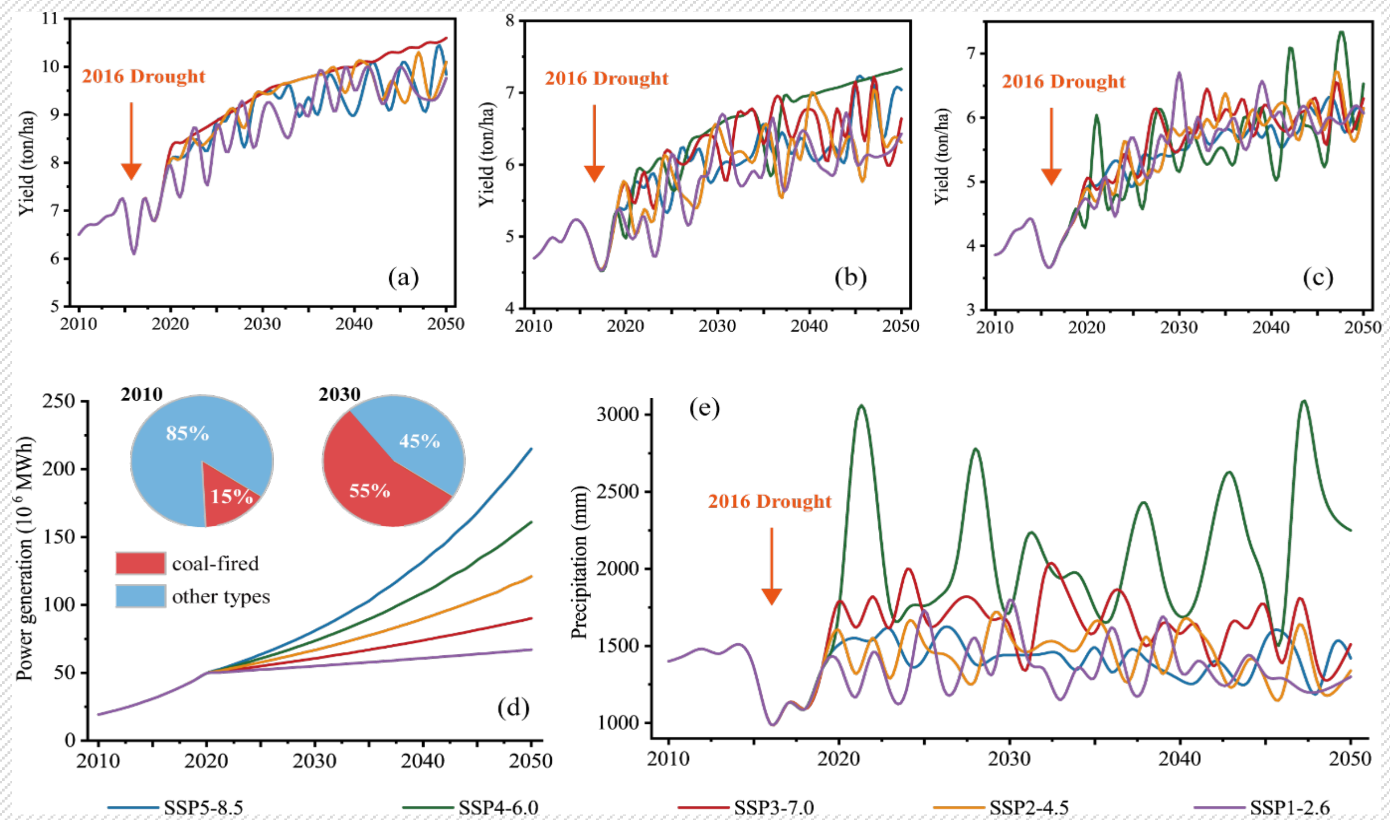


Figure 2. The yield of spring (a), autumn (b), and winter (c) rice, power generation (d), and precipitation (e) in different climate and socio-economic scenarios

Nexus analysis found a strong connection among food, energy, and water systems in the MRD. Specifically, there is a clear linear trend between coal-fired power generation and water withdrawal; a strong connection between the food and water sector also reveals that rice cultivation in the MRD heavily relies on irrigation. However, the relationship between the food and energy sector is relatively weak. The framework developed in this research help to gain a comprehensive understanding of the climate and socio-economic impact on regional sustainability through FEW Nexus and thus can be used in other river basins that face similar issues.

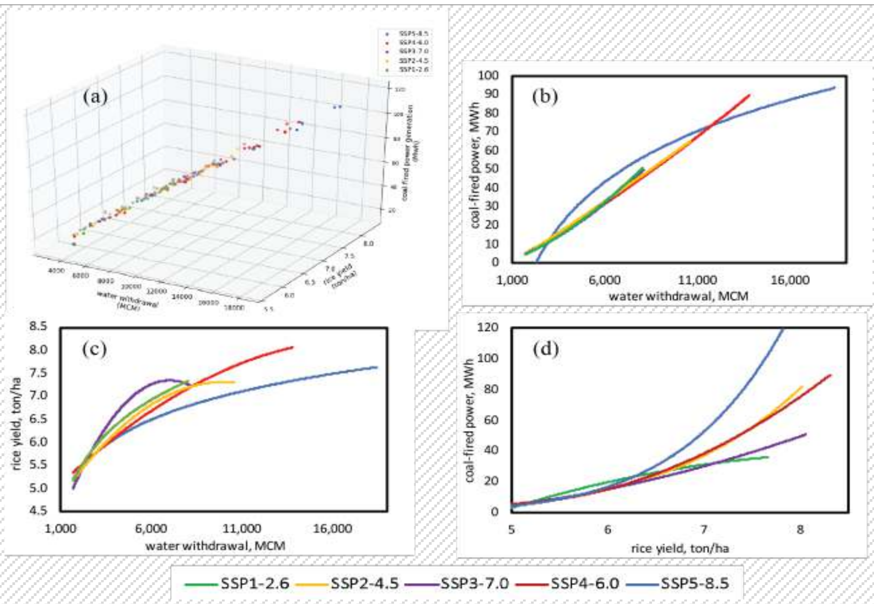


Figure 3. FEW nexus (a), food-energy (b), food-water (c), and energy-water (d) relationship

The results were published in **Resources, Conservation and Recycling**

Full article link:

https://www.sciencedirect.com/science/article/pii/S0921344920307084

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