THE UNIVERSITY OF HONG KONG
Centre for Water Technology and Policy

Inter-disciplinary Forum

"Climate-resilient Urban Water Systems: New Technologies and Policy Challenges"

Report on Plenary Session 2: Climate Change Risks

Date: 29 May 2018
Time: 11:00 a.m. – 12:45 p.m.

Plenary Session 2: Climate Change Risks
Chaired by:
Dr. Lishan Ran
Department of Geography
The University of Hong Kong

"Water Challenges in the Face of Climate Change and Extreme Weather"
Professor David Chen
Department of Geography and Resource Management
Chinese University of Hong Kong

"Evaluation of Socioeconomic Droughts under Climate Changes"
Dr. Ji Chen
Department of Civil Engineering
The University of Hong Kong

"Urban Flooding: From Flood Control to Integrated Management"
Professor Zongxue Xu
Deputy Dean, College of Water Sciences
Beijing Normal University

"Water Challenges in the Face of Climate Change and Extreme Weather"

by Professor David Chen,
Department of Geography and Resource Management,
Chinese University of Hong Kong

Water challenges brought by climate change

- The risk of flooding of many human settlements is much higher, as global warming has resulted in a number of environmental consequences, including an increasing number of heavy rainstorm events, sea-level rise and storm surges.
- Water availability in many water-scarce regions falls further as a result of higher environmental temperature, less frequent precipitation, reduction in groundwater recharge, and lowering of water table that further undermines streamflow.
- In winter, more precipitation fell as rain than snow. The falling rain/snow ratio reduced water storage in snow. As snow melts before the summer arrives, water availability in summer, when water demand is at peak, is reduced. Heat waves associated with climate change magnify the problem further.
- The rise of sea level and intrusion of salt water threaten freshwater resources in deltaic regions and coastal wetlands, such as mangroves.

Major findings

- ISI-MIP simulations can model different floods and water availability scenarios under climate change. Although multi-model ensemble medians can represent floods and water availability well, they tend to underestimate floods and overestimate water availability.
- Compared to hydrological models (HMs), global circulation models (GCMs) play a more significant role in determining the spatial patterns of changes in floods and water availability. GCM variances dominate the uncertainties of floods and water availability in humid and semi-humid regions in eastern China, while HM variances project changes in arid and semi-arid regions in northwestern China.
- According to the worst climatic scenario (i.e. RCP 8.5), flood incidents will increase, but water availability will decrease in south China between 2070 and 2099. Reduced water availability could intensify conflicts available water resources and worsen water conflicts between southern China and water-short northern China.
- In the RCP2.6 scenario, flood incidents increase while water availability changes negligibly across China. Generally, flooding in China in the future increases more significantly than water availability. Extreme flood incidents would be more frequent than less extreme ones.
- More frequent extreme precipitation events are likely to increase the number of future flood incidents in China significantly. Under RCP8.5, although extreme precipitation events would become more common in southern China, only negligible change is expected for mean precipitation amount. Evapotranspiration is expected to increase with increasing global temperature, which is going to reduce water availability in southern China.

- For northern China, increasing amount of evapotranspiration will also reduce water availability. However, change of precipitation would become more likely, thus resulting in an increase in water availability.
- Precipitation changes combined with increase of evapotranspiration as a result of riding temperature will reduce water availability. In northern China, although evapotranspiration increases, there is greater tendency to precipitate, leading to an increase in water availability. Changes in precipitation would be more apparent than changes in number of floods and water availability amount.

Concluding remarks

- Different models show similar results regarding changes in flood frequency and intensity, but much varied results regarding water availability. The different modelling outcomes could be attributed to greater uncertainties associated with the simulated mean precipitation from GCMs.
- A major limitation of this study is that the changes in vegetation cover, as a result of changing climate and hydrologic conditions, have not been taken into consideration.

"Evaluation of Socioeconomic Droughts under Climate Changes"

By Dr. Ji Chen
Department of Civil Engineering,
The University of Hong Kong

Background

- Drought is a complex natural hazard that could cause widespread damage to societal properties and even lives. Generally speaking, socioeconomic drought occurs when water resources available cannot meet water demand, as a result of weather-related shortfall in water supply.

Use of Socioeconomic Drought Index (SEDI)

- The Socioeconomic Drought Index (SEDI) was developed to identify and evaluate socioeconomic drought events on different severity levels (i.e., slight, moderate, severe, and extreme levels) in the context of climate change:
  - The minimum in-stream water requirement (MWR) is determined through synthetically evaluating the requirements of water quality, ecology, navigation, and water supply.
  - The drought month(s) can be identified by calculating the amount of monthly water deficit, which is derived by monthly streamflow minus the MWR
  - According to the cumulative water deficit calculated from the monthly water deficit, drought duration (i.e., the number of continuous drought months) and water shortage (i.e., the largest cumulative water deficit during the drought period) can be detected.
  - The SEDI value of each socioeconomic drought event can be calculated through integrating the impacts of water shortage and drought duration.

Major findings

- The MWR value of the East River basin for each year during 2010–2099 is obtained by considering the change in water demand in future, which can be a target of the integrated water resources management in this river basin and a reference to other river basins.
- The SEDI is validated through historical drought analysis. The index is then applied to analyze future droughts. The trends of the simulated streamflow derived from 52 datasets were analyzed. Socioeconomic drought events during 2020–2099 are also identified. The results indicate that a number of socioeconomic drought events, which are expected to be severer than the 1963 drought, may occur in future.
- Through analyzing the impact of the Xinfengjiang (XFJ) Reservoir on future droughts, this study indicates that most of the identified socioeconomic drought events can be mitigated by reserving an effective storage of Xinfengjiang Reservoir at 70%. Moreover, it is suggested that at least 30% of the effective storage should be reserved in the XFJ Reservoir at the end of the flood season to overcome most of the severe and extreme socioeconomic drought events.

"Urban Flooding: From Flood Control to Integrated Management"

By Professor Zongxue Xu
Deputy Dean, College of Water Sciences,
Beijing Normal University

Background

- Urban storage capacity has been reduced by urbanization. The amount of surface runoff has increased by 3.5 times after urbanization.
- The coefficient of runoff showed a significant increase from 0.12 to 0.41, and the amount of infiltration decreased from 88% to 60%.
- To control flooding and mitigate impacts of drought, it is important to promote a new form of development in greater harmony with nature:
  - Flood: Make room for flood water
  - Drought: Water conservation
  - Pollution: Green development

Major findings

- Short- duration but intense bursts of rainfall are the primary cause of flash flood. Flooding risk can be reduced or tackled by creating sponge cities and implementation of timely flood relief measures.
- Low impact development and flood diversion can effectively mitigate flood risks and reduce flood peak and volume of flood.
- Flooding risks increases significantly as the extent of urbanization increases.
- The peak flow of 20-year return-period after urbanization is greater than that of 100-year return-period before urbanization.
- Integrated management and good governance are better solutions to flood risk management. The crux of flood control lies in development of a good governance system to drive technology diffusion.

Panel Discussion

Q1: With global warming, do you think an increase in sea surface temperature will lead to an increase in intensity and frequency of typhoon strikes?

A1: Normally, typhoon season in Hong Kong starts in June and ends in October. Certainly, if sea surface temperature increases, typhoon development is more likely. Precipitation amount will also increase by 10 to 20%, thus resulting in an increase in local water storage.

Q2: According to the model, can we say that there must be a drought in the next 30 years? Is it going to affect the water supply of Hong Kong?

A2: There are still uncertainties pertaining to precipitation forecasts. Some models tell us that an increasing trend for streamflow should be expected, but other models tell us otherwise. In general, the possibility of drying up of reservoirs will increase in the near future with climate change. Even though the models cannot tell when exactly a drought will happen, they are useful to stimulate climate change at a macro-scale.

HKU Interdisciplinary Forum, 29 May 2018

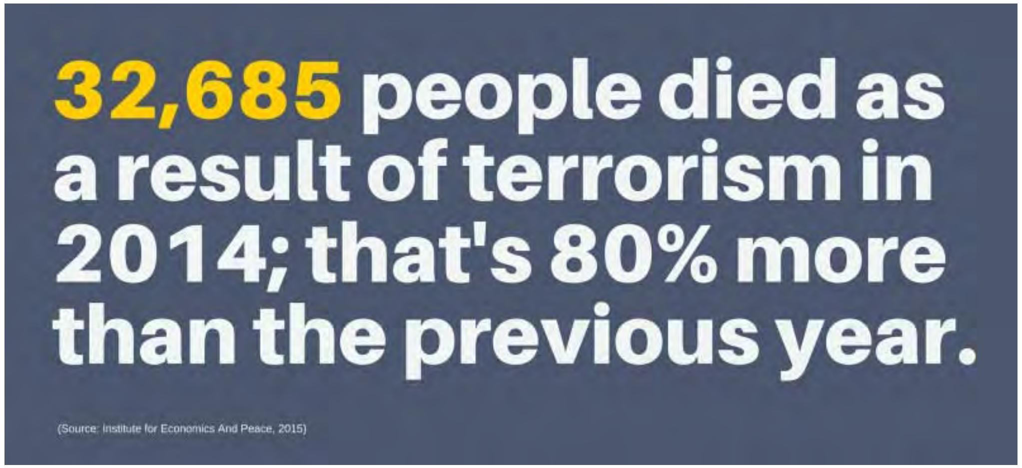
Water challenges in the face of climate change and extreme weather

CHEN Yongqin David (陳永勤)
Department of Geography and Resource Management
Institute of Environment, Energy and Sustainability
The Chinese University of Hong Kong
Email: *ydavidchen@cuhk.edu.hk*

Three major threats to the world:
Natural disasters, terrorism and pandemic diseases

These are common and recurrent, but regional and sporadic.

Climate change is global, persistent and irreversible!!



2016 set to be world's hottest year on record, says UN

中国时间：12:19 2016年11月20日星期日

环境

2016.11.15 07:11

联合国：2016年超过去年成为最热之年

2016/07/22, 國際

2016年恐成史上最熱的一年，世界氣象組織：全球暖化發生比預期快

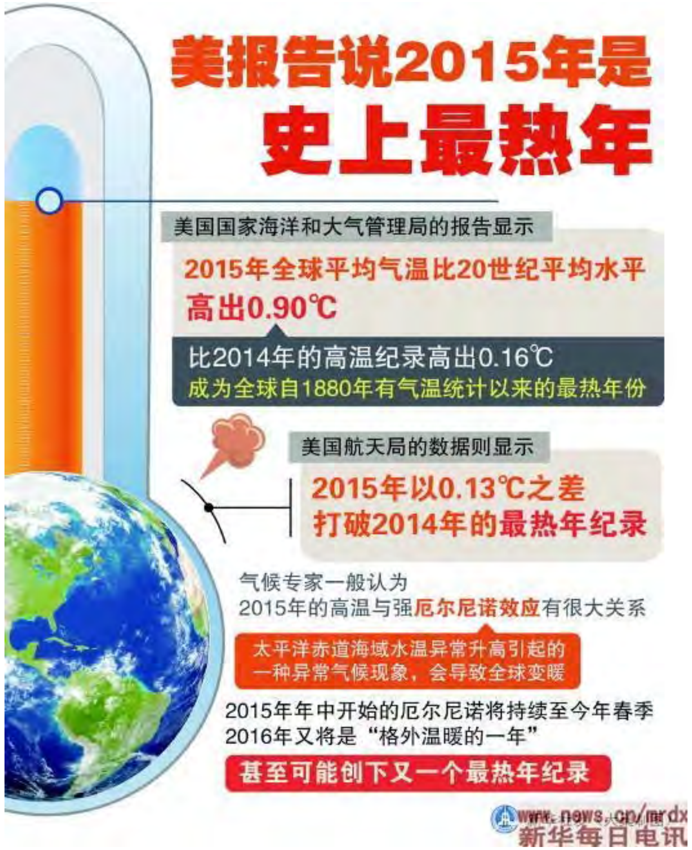
A23 | 明報 SUNDAY | 2015年 1月18日 | 星期日

主編推介

2014年史上最熱

10年3破紀錄 反駁暖化停止論

Global warming **hiatus**/pause/slowdown (1998 – 2013)



2017 set to be one of top three hottest years on record

Data so far this year points to 2017 continuing a long-term trend of record breaking temperatures around the world, says World Meteorological Organization

Consequences of Global Warming: Three biggest challenges

Enhance greenhouse effect → Rising temperature

Thermal expansion of sea water & melting of snow on land → Sea level rise

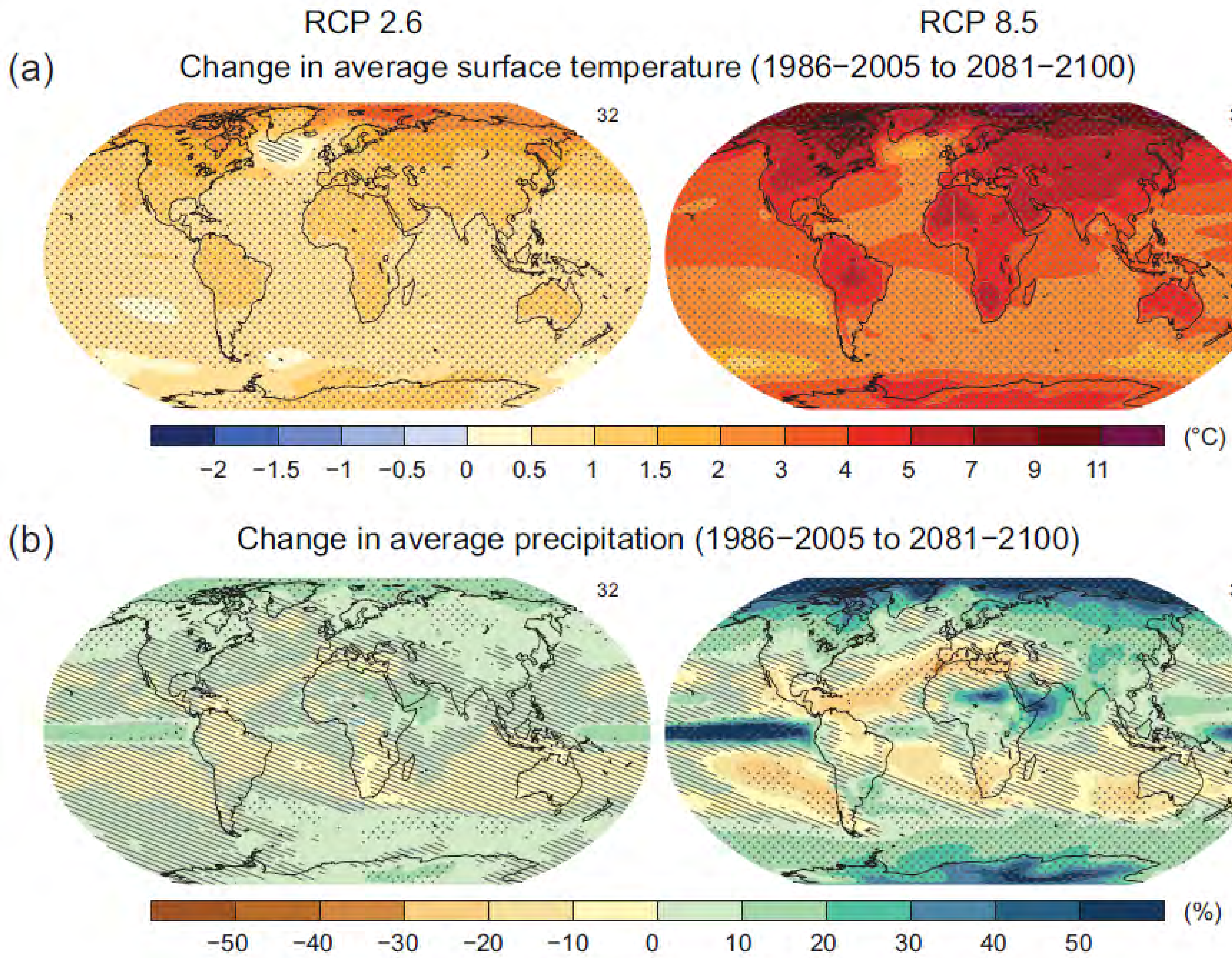
Change in atmospheric circulation and enhance the water cycle → Regional differences in precipitation and increase in occurrence of **extreme weather and climate events**

Water is particularly sensitive and vulnerable to climate change because hydrologic cycle is fundamentally controlled by regional and global climate

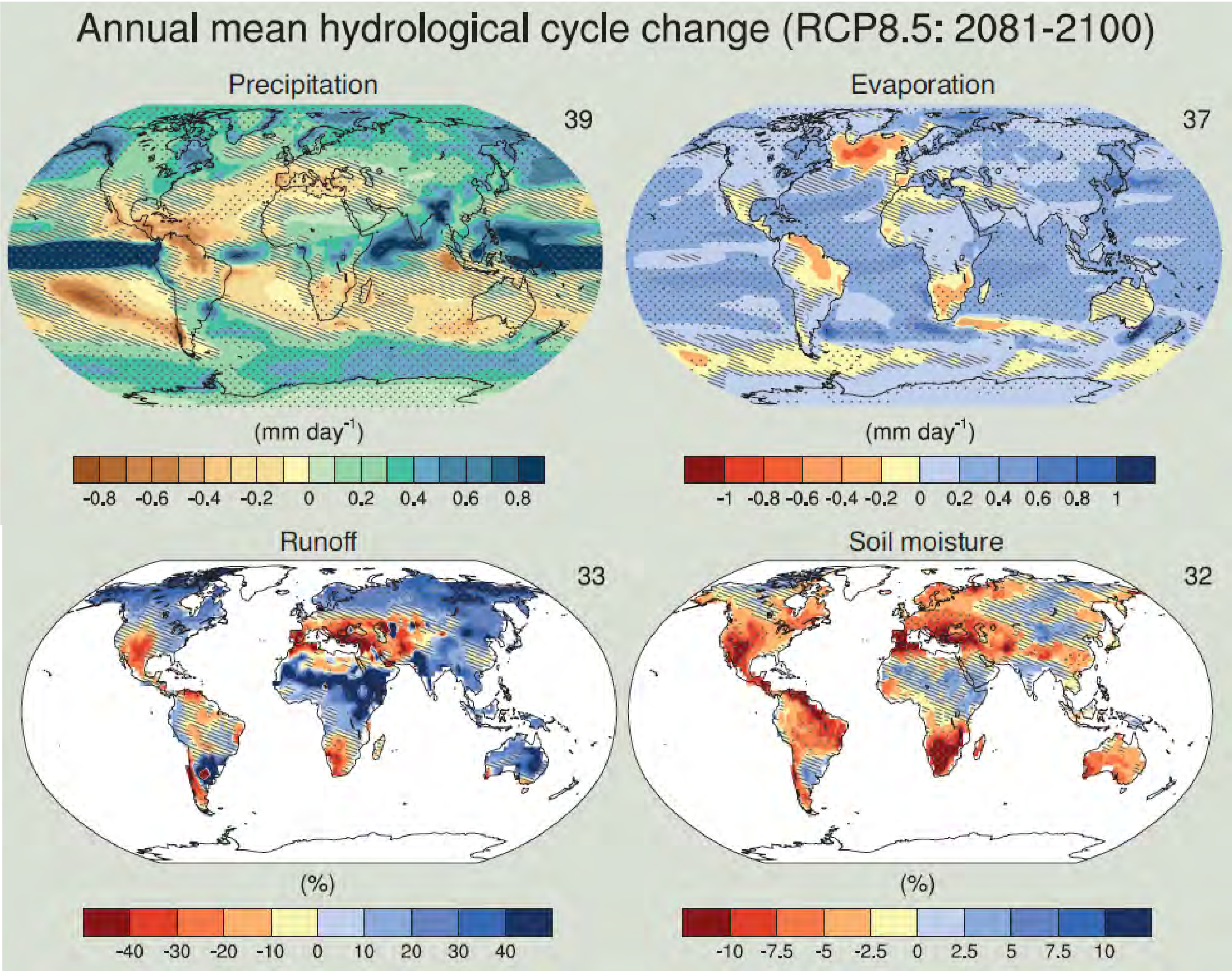
Basic water budget: Runoff = Precipitation - Evapotranspiration

The warming climate intensifies the hydrologic cycle, generates more tropical cyclones and causes sea level rise

- Increase evapotranspiration - higher atmospheric water vapor concentrations because saturation vapor pressure increases at the Clausius-Clapeyron (CC) rate of about 7% per one degree Celsius, water vapor is a GHG and enhances greenhouse effect
- More clouds produce more precipitation overall and disturb the global energy balance
- Change precipitation patterns - spatial and temporal distributions, less frequent but more intensive rainfall, more rain and less snow, earlier snow melt, changing the timing of peak flows
- Change runoff and streamflow patterns – diverse regional responses of hydrologic cycle, more frequent and intense floods and droughts
- Increase in areas, frequency and intensity of tropical cyclone formation
- Sea level rise resulting from melting of cryosphere and thermal expansion of sea water

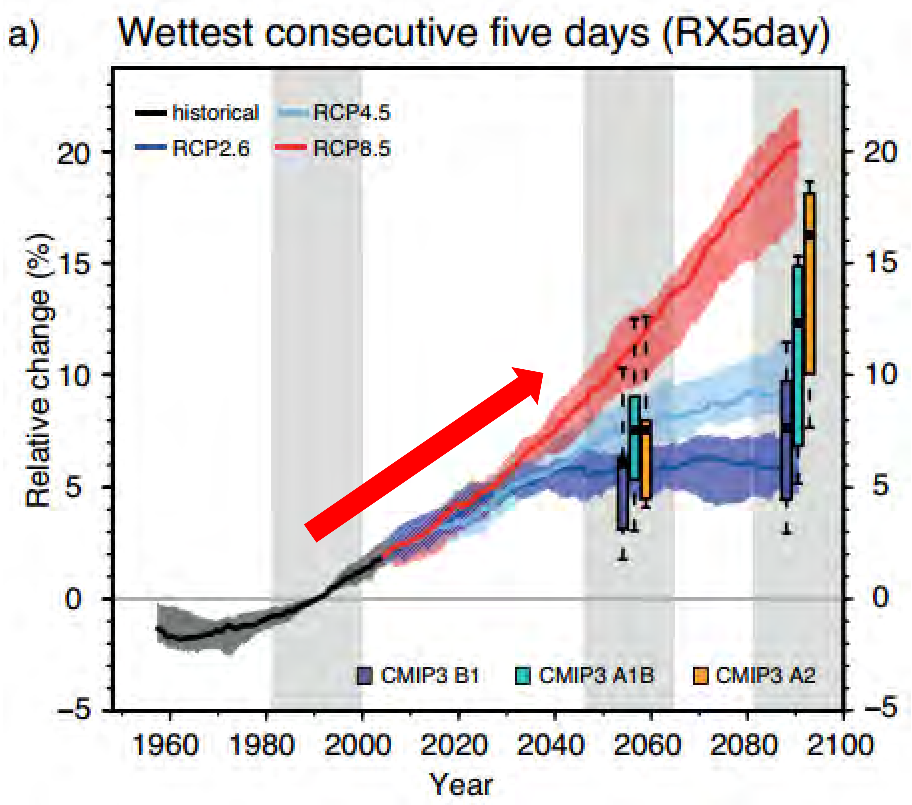


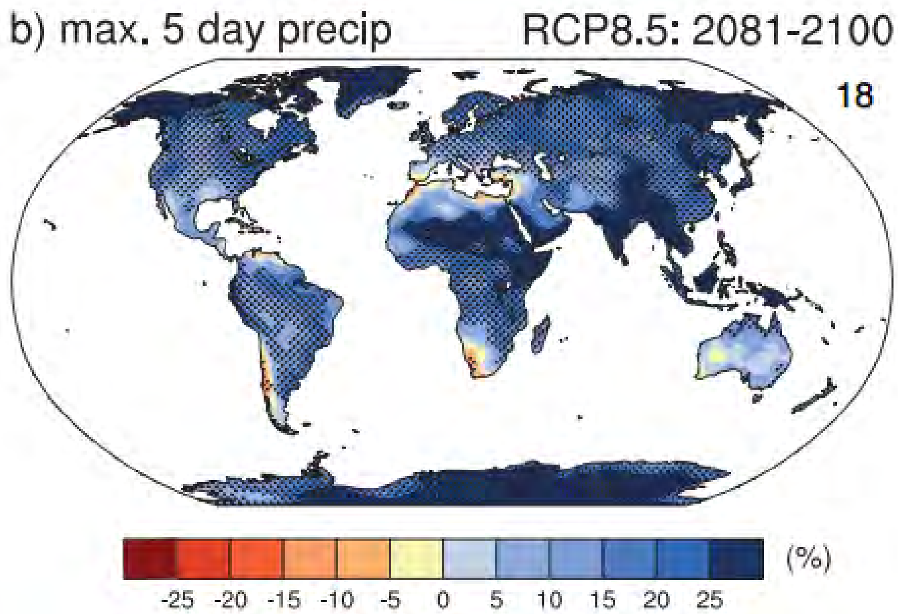
Maps of CMIP5 multi-model projections (Source: IPCC AR5, 2013)



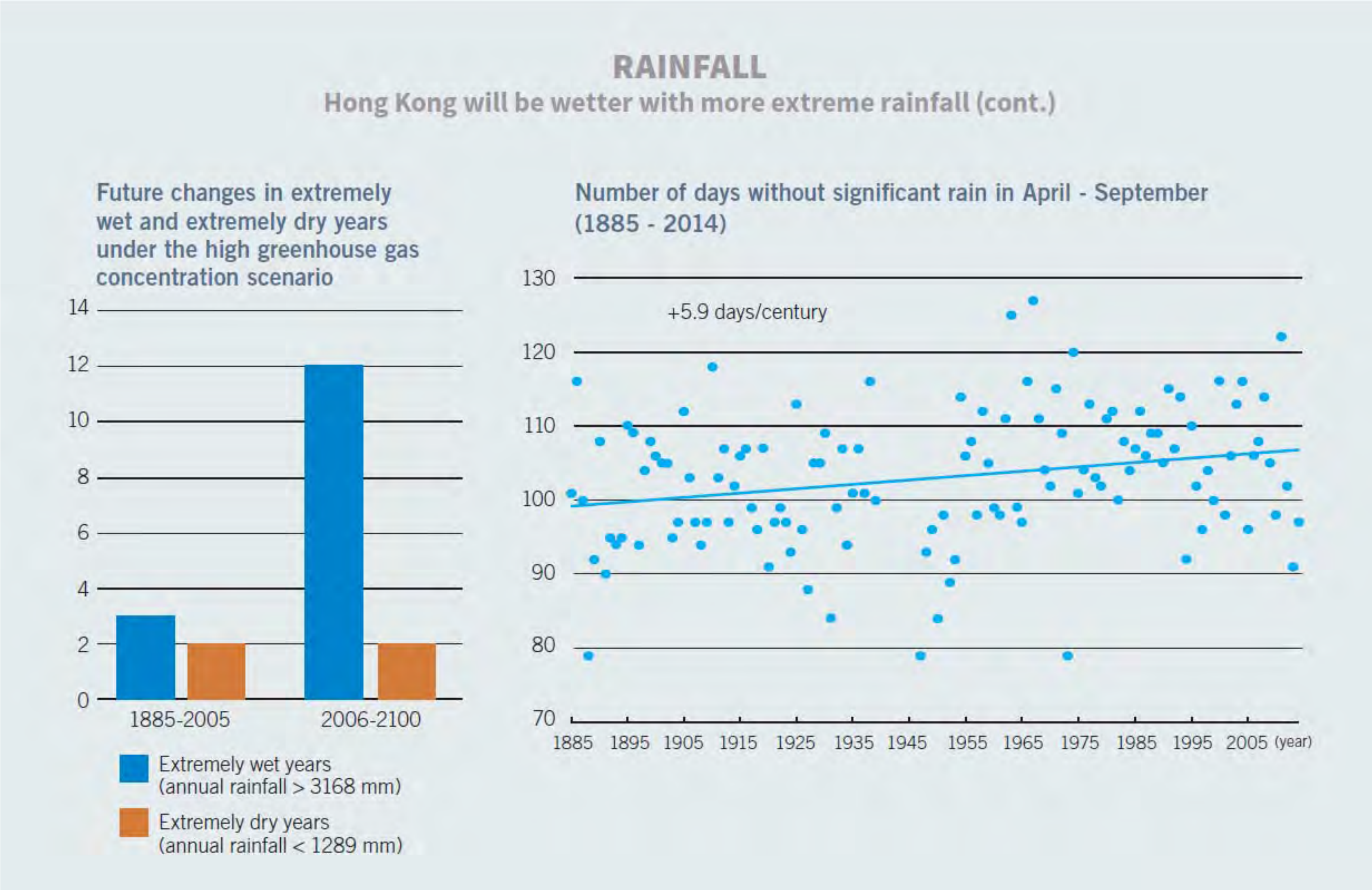
Maps of CMIP5 multi-model projections (Source: IPCC, AR5, 2013)

Intensifying precipitation extremes across the globe

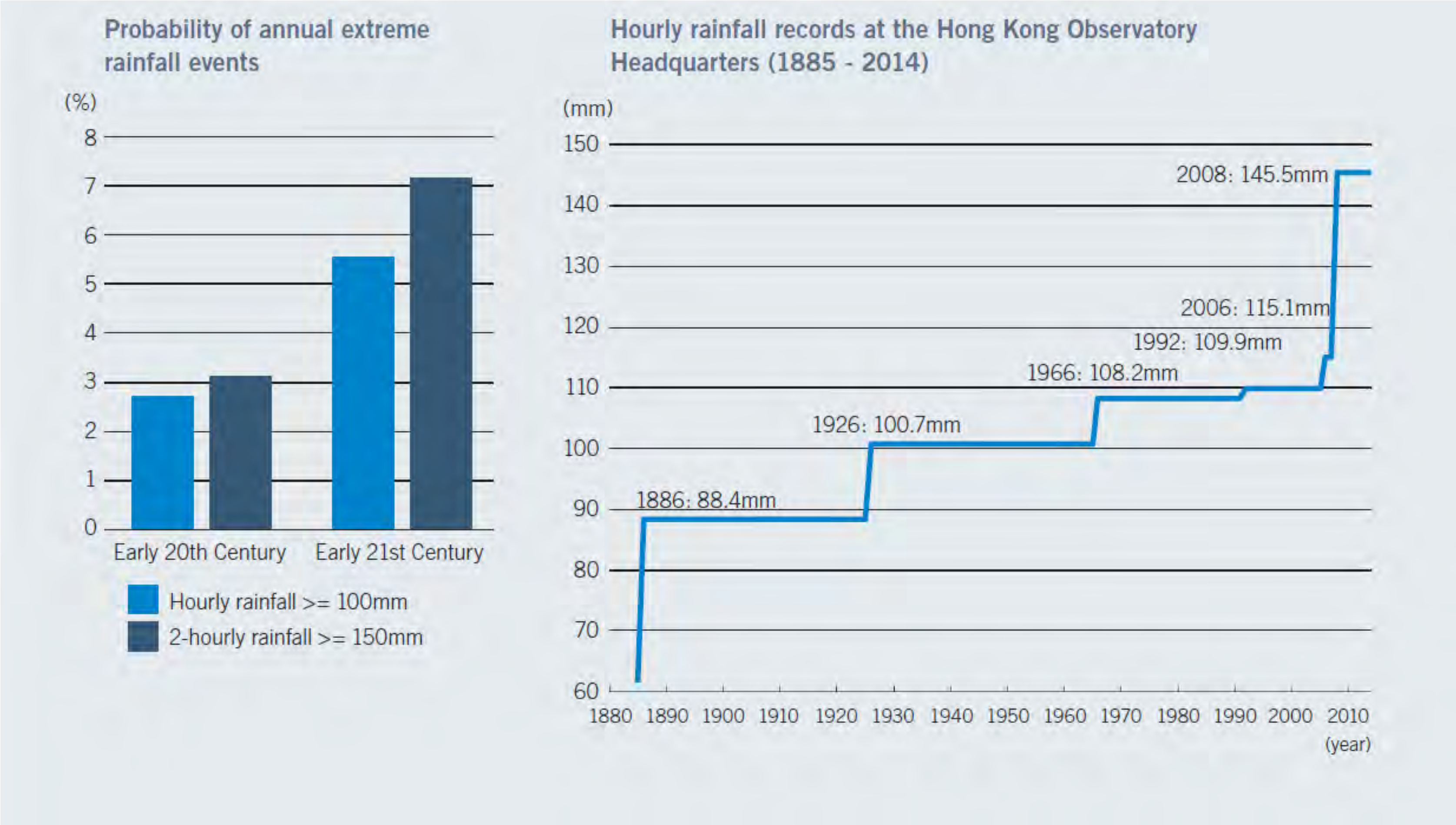




IPCC AR5 (2013)



Source: Hong Kong Climate Change Report 2015



Source: Hong Kong Climate Change Report 2015

Hydrologic effects and water problems caused by global warming

- Widespread increase in risk of flooding for many human settlements due to increased heavy rainstorm events and sea-level rise, compound floods caused by upstream river discharge (fluvial), localized rainstorm (pluvial) and storm surge under sea level rise (coastal)

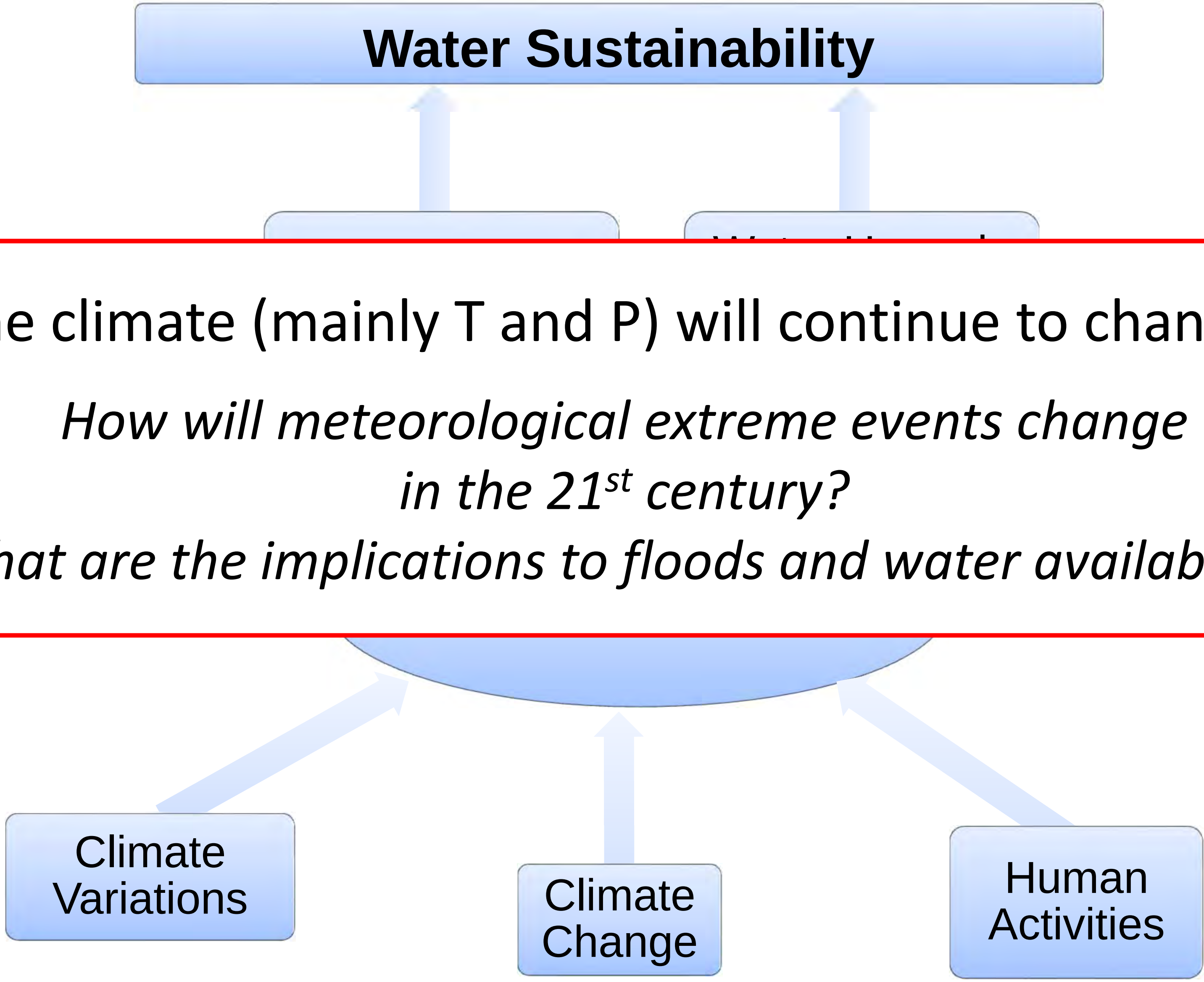
- Decrease in streamflow and water availability in many water-scarce regions because of higher ET and less frequent precipitation, reduction in groundwater recharge and lowering of water table

- More winter precipitation may fall as rain, resulting in decreased water storage in snow, earlier snow melt reduces water available in summer with higher demand, especially as global warming may induce more heat wave

- Sea level rise and salinity intrusion threaten freshwater resources in the deltaic regions

- Loss of wetlands and mangroves in coastal areas due to sea level rise

Water challenges under climate change and human disturbance

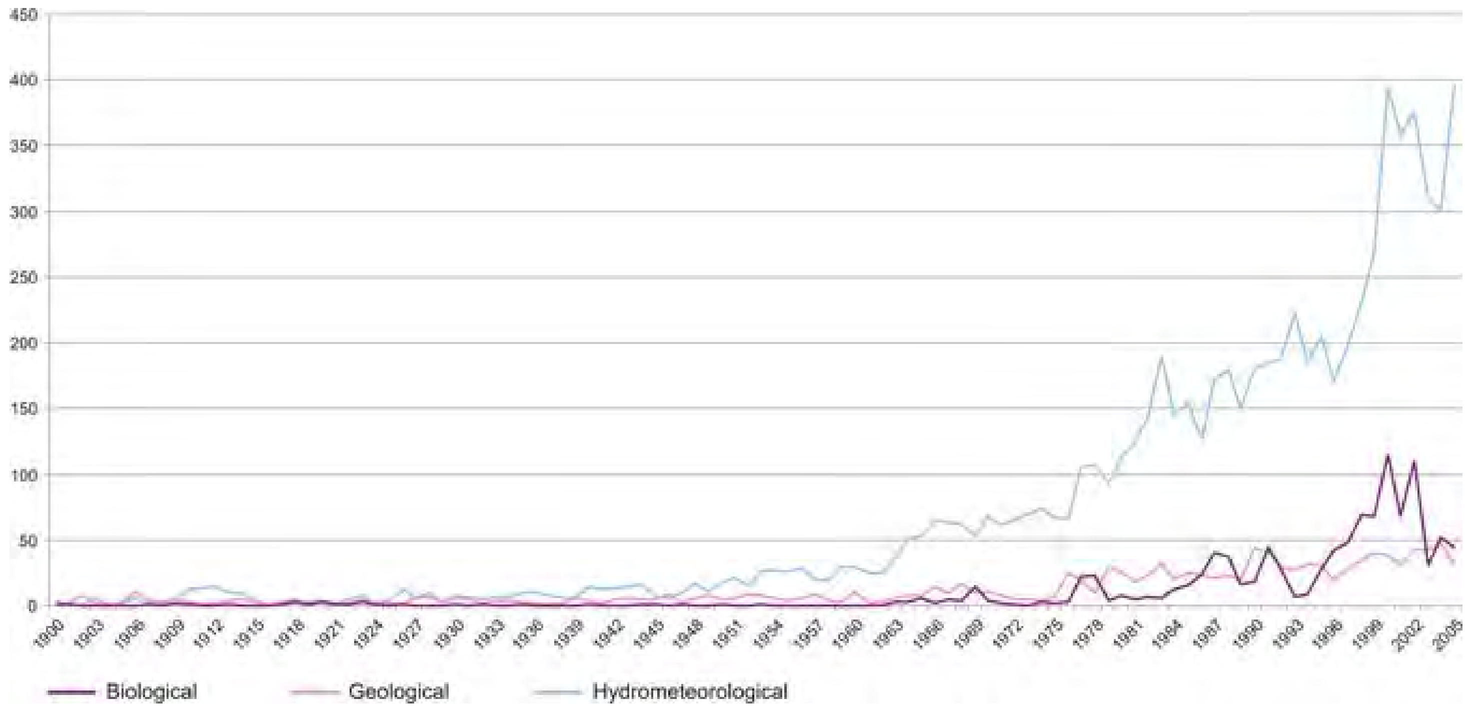


The climate (mainly T and P) will continue to change!!

How will meteorological extreme events change in the 21st century?

What are the implications to floods and water availability?

Number of natural disasters registered in EM-DAT (Emergency Events Database) 1900-2005

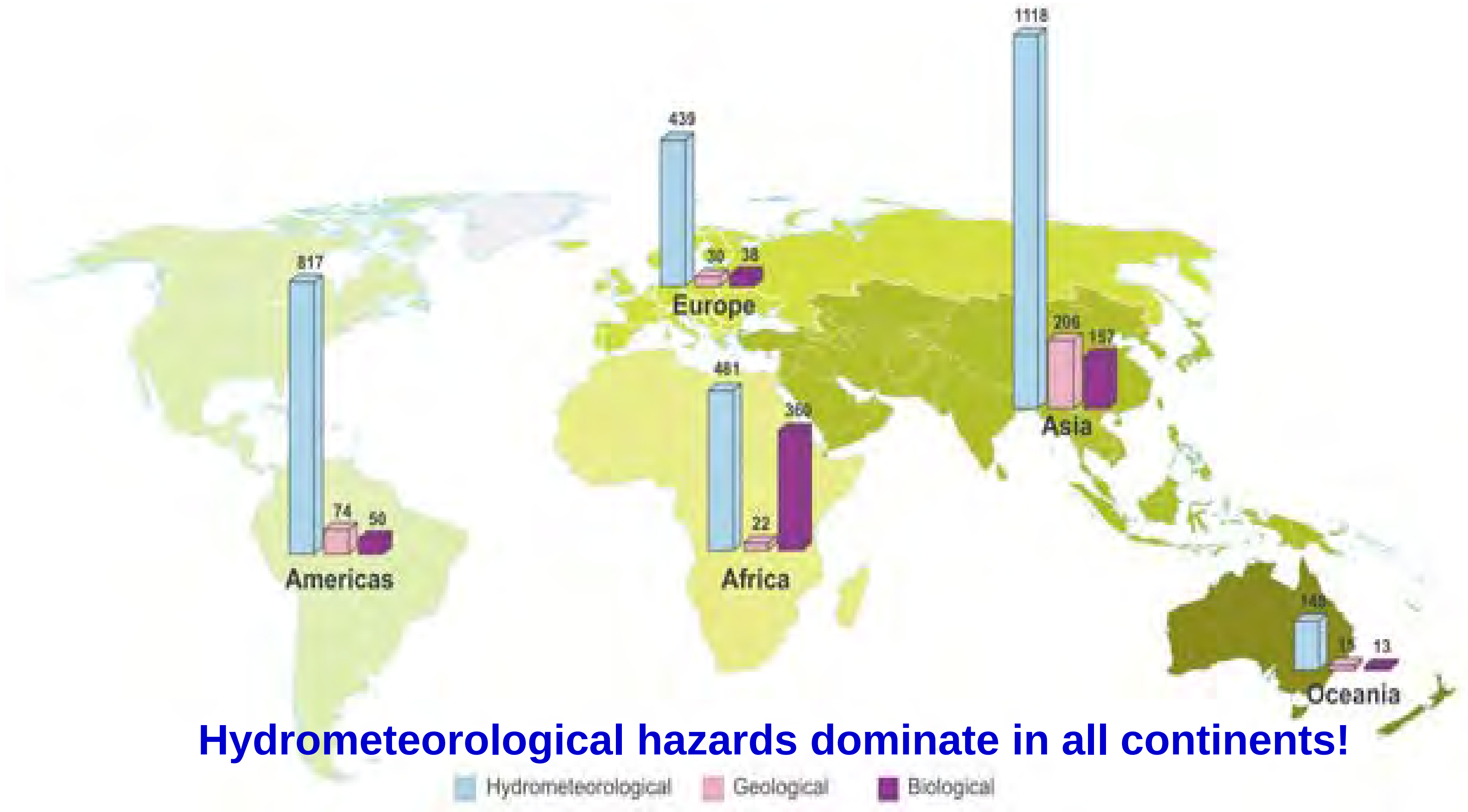


Distribution of natural disasters: by origin (1900-2005, by decades*)

	1900-1909	1910-1919	1920-1929	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2005	Total
Hydrometeorological	28	72	56	72	120	232	463	776	1 498	2 034	2 135	7 486
Geological	40	28	33	37	52	60	88	124	232	325	233	1 252
Biological	5	7	10	3	4	2	37	64	170	361	420	1 083
Total	73	107	99	112	176	294	588	964	1 900	2 720	2 788	9 821

Source: EMDAT/ISDR

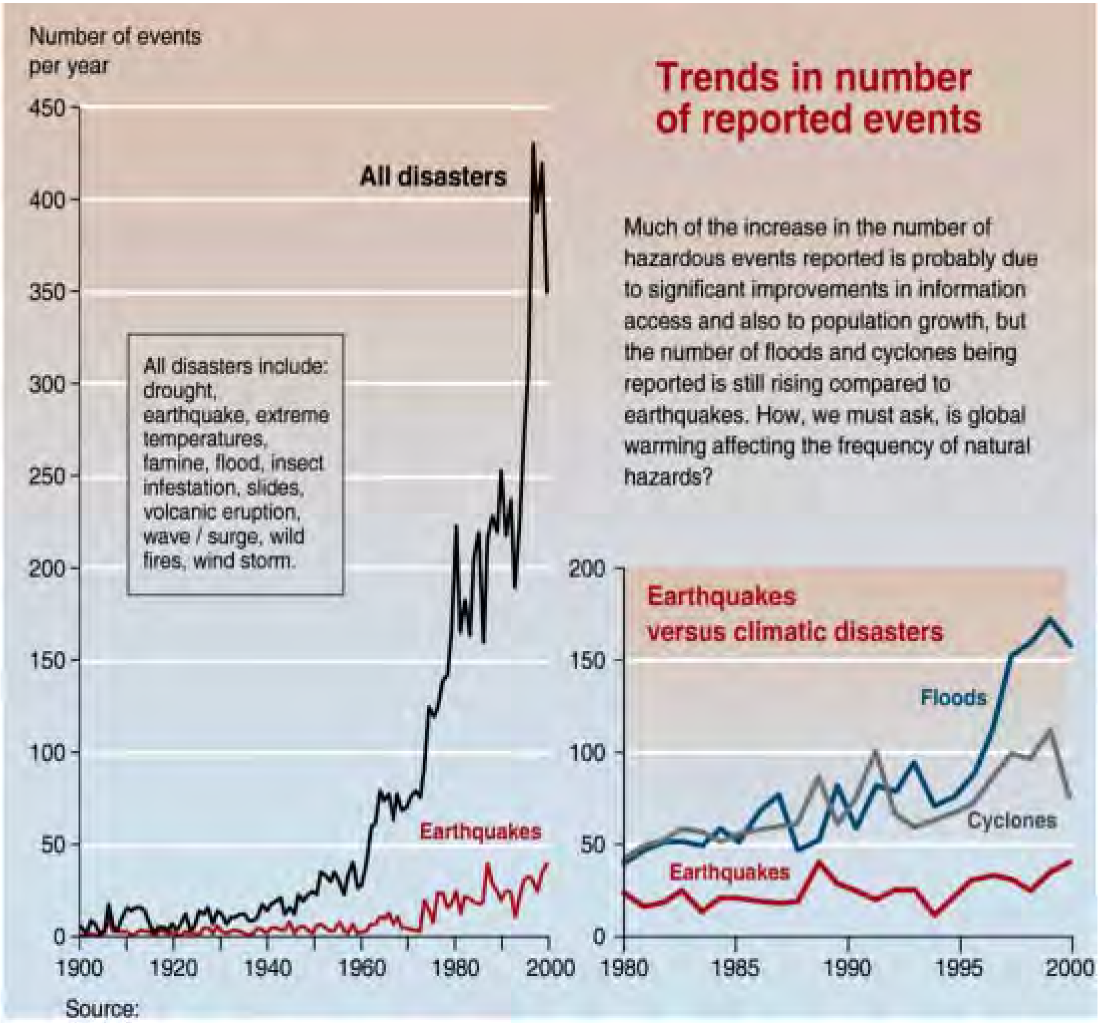
Number of natural disasters by origin 1995 - 2004: regional distribution



Hydrometeorological hazards dominate in all continents!

Source: EMDAT/ISDR

Climate change and global warming: Is the warming climate becoming more and more variable?



Source: EMDAT/ISDR

Increasing risk of great floods in a changing climate

P. C. D. Milly*, R. T. Wetherald†, K. A. Dunne* & T. L. Delworth†

** US Geological Survey, GFDL/NOAA; and † Geophysical Fluid Dynamics Laboratory/NOAA, P.O. Box 308, Princeton, New Jersey 08542, USA*

Radiative effects of anthropogenic changes in atmospheric composition are expected to cause climate changes, in particular an intensification of the global water cycle[1] with a consequent increase in flood risk[2]. But the detection of anthropogenically forced changes in flooding is difficult because of the substantial natural variability[3]; the dependence of streamflow trends on flow regime[4,5] further complicates the issue. Here we investigate the changes in risk of great floods—that is, floods with discharges exceeding 100-year levels from basins larger than 200,000 km^2—using both streamflow measurements and numerical simulations of the anthropogenic climate change associated with greenhouse gases and direct radiative effects of sulphate aerosols[6]. We find that the frequency of great floods increased substantially during the twentieth century. The recent emergence of a statistically

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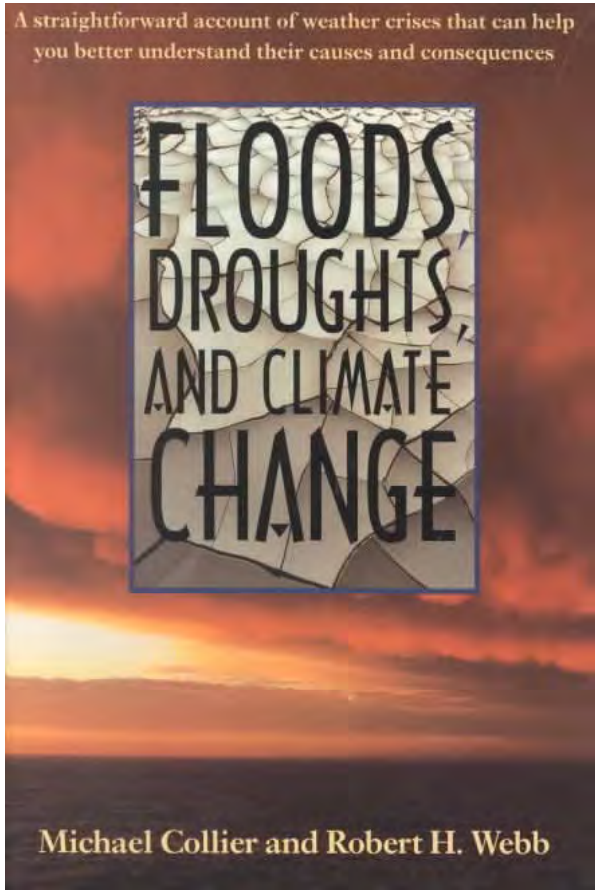


Global projections of changing risks of floods and droughts in a changing climate

YUKIKO HIRABAYASHI , SHINJIRO KANAE , SEITA EMORI , TAIKAN OKI & MASAHIDE KIMOTO

To cite this article: YUKIKO HIRABAYASHI , SHINJIRO KANAE , SEITA EMORI , TAIKAN OKI & MASAHIDE KIMOTO (2008) Global projections of changing risks of floods and droughts in a changing climate, Hydrological Sciences Journal, 53:4, 754-772, DOI: 10.1623/hysj.53.4.754

Future Changes in Floods and Water Availability across China: Linkage with Changing Climate and Uncertainties

JIANFENG LI

Department of Geography and Resource Management, The Chinese University of Hong Kong, and Department of Geography, Hong Kong Baptist University, Hong Kong, China, and CSIRO Land and Water, Canberra, Australian Capital Territory, Australia

YONGQIN DAVID CHEN

Department of Geography and Resource Management, and Institute of Environment, Energy and Sustainability, The Chinese University of Hong Kong, Hong Kong, China

LU ZHANG

CSIRO Land and Water, Canberra, Australian Capital Territory, Australia

QIANG ZHANG

Department of Water Resources and Environment, and Key Laboratory of Water Cycle and Water Security in Southern China of Guangdong High Education Institute, Sun Yat-sen University, Guangzhou, and School of Earth Sciences and Engineering, Suzhou University, Anhui, China

FRANCIS H. S. CHIEW

CSIRO Land and Water, Canberra, Australian Capital Territory, Australia

(Manuscript received 27 April 2015, in final form 18 February 2016)

ABSTRACT

Future changes in floods and water availability across China under representative concentration pathway 2.6 (RCP2.6) and RCP8.5 are studied by analyzing discharge simulations from the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) with the consideration of uncertainties among global climate models (GCMs) and hydrologic models. Floods and water availability derived from ISI-MIP simulations are compared against observations. The uncertainties among models are quantified by model agreement. Only model agreement >50% is considered to generate reliable projections of floods and water availability and their relationships with climate change. The results show five major points. First, ISI-MIP simulations have acceptable ability in modeling floods and water availability. The spatial patterns of changes in floods and water availability highly depend on the outputs of GCMs. Uncertainties from GCMs/hydrologic models predominate the uncertainties in the wet/dry areas in eastern/northwestern China. Second, the magnitudes of floods throughout China increase during 2070–99 under RCP8.5 relative to those with the same return periods during 1971–2000. The increase rates of larger floods are higher than those of the smaller ones. Third, water availability decreases/increases in southern/northern China under RCP8.5, but changes negligibly under RCP2.6. Fourth, more severe floods in the future are driven by more intense precipitation extremes over China. The negligible change in mean precipitation and the increase in actual evapotranspiration reduce the water availability in southern China. Fifth, model agreements are higher in simulated floods than water availability because increasing precipitation extremes are more consistent among different GCM outputs compared to mean precipitation.

Coupled Model Intercomparison Project: CMIP3 and CMIP5

- Under WCRP of WMO the Working Group on Coupled Modelling (WGCM) established CMIP as a standard experimental protocol for studying the output of coupled atmosphere-ocean general circulation models (AOGCMs). CMIP provides a community-based infrastructure in support of climate model diagnosis, validation, intercomparison, documentation and data access. Virtually the entire international climate modeling community has participated in this project since its inception in 1995.

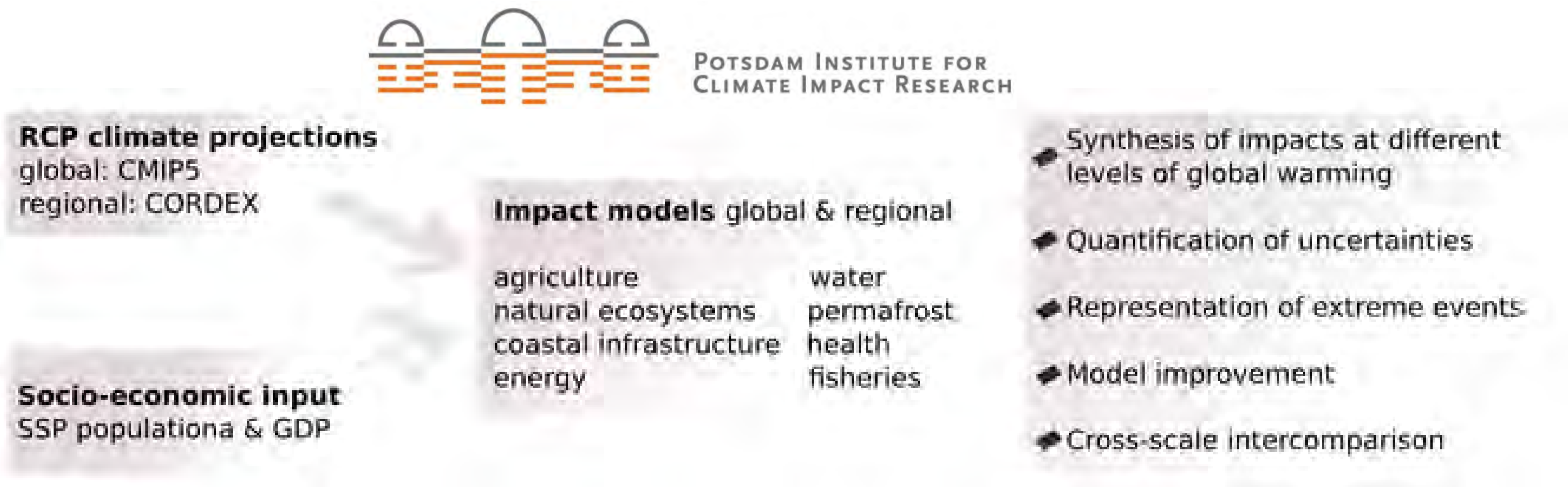
- CMIP3 multi-model dataset for AR4 (1995-2007): SRES (Special Report on Emission Scenarios) B1 (540 ppm), A1B (700 ppm) and A2 (840 ppm)

- CMIP5 multi-model dataset for AR5 (2008-2013): Representative Concentration Pathway (RCP2.6, RCP4.5, RCP6.0, RCP8.5) are mitigation scenarios that assume policy actions will be taken to achieve certain emission targets.

Source: WCRP website

Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP)

ISI-MIP is a community-driven modeling effort bringing together impact models across sectors and scales to create consistent and comprehensive projections of the impacts of different levels of global warming (PIK website).



5 GCMs

GFDL-ESM2M
HadGEM2-ES
IPSL-CM5A-LR
MIROC-ESM-CHEM
NorESM1-M

×

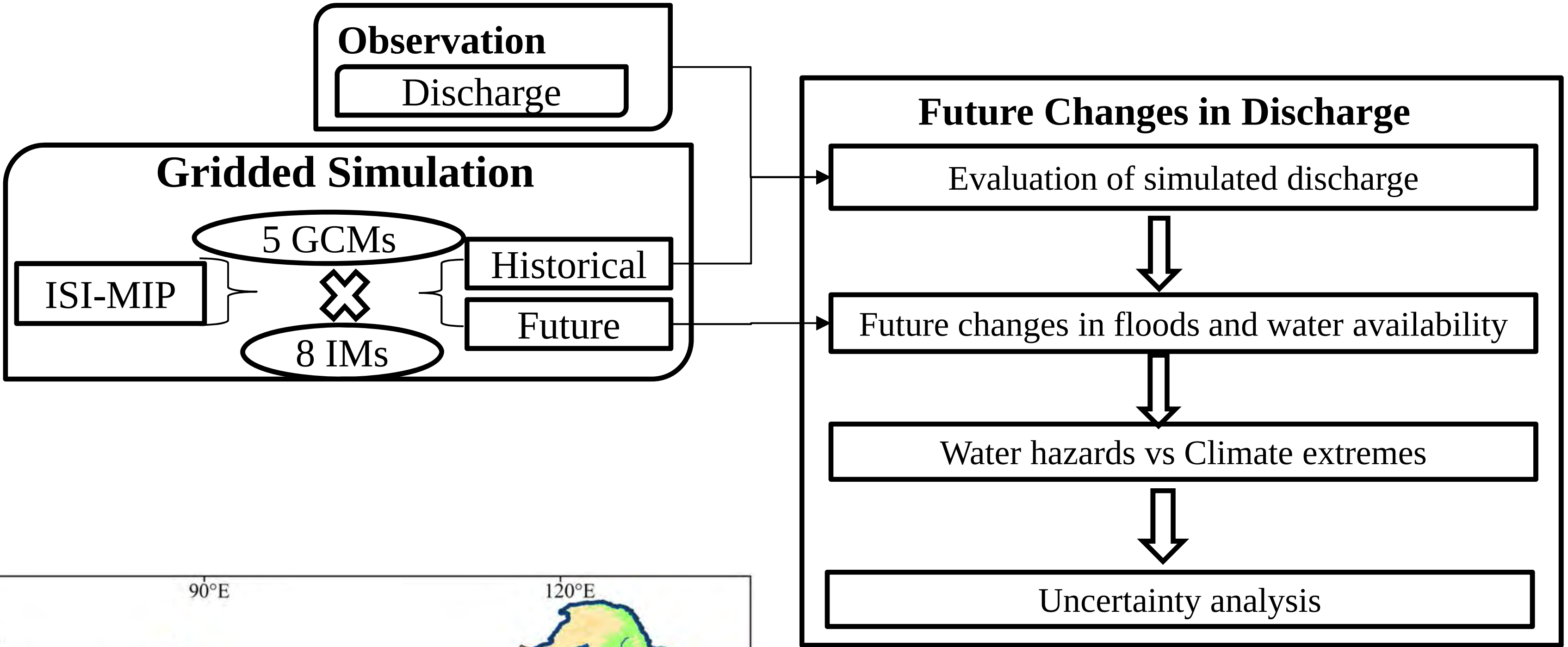
8 HMs

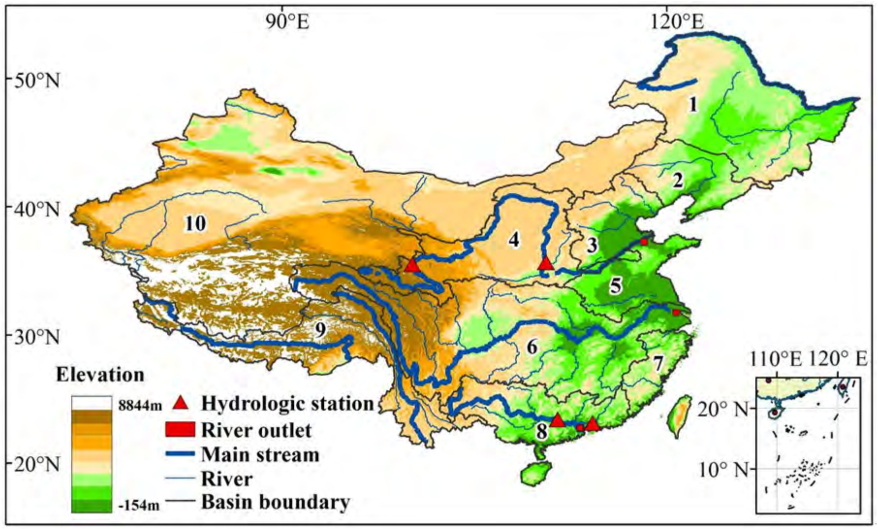
DBH
H08
Mac-PDM
MATSIRO
MPI-HM
PCR-GLOBWB
VIC
WBM

=

40 Combinations

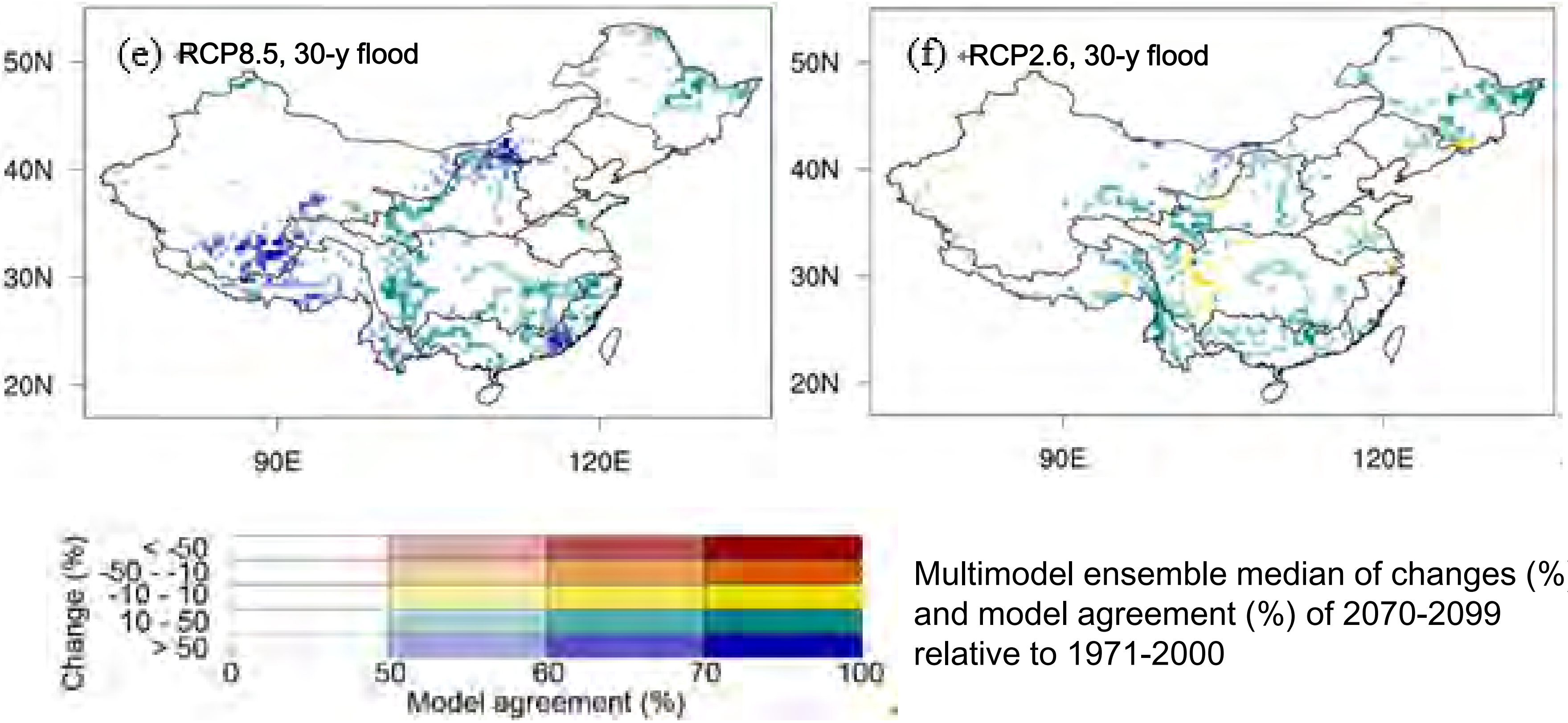
Research framework and observed discharge





Observed daily streamflow of 4 major hydrologic stations in the Pearl River and the Yellow River from 1971-1980

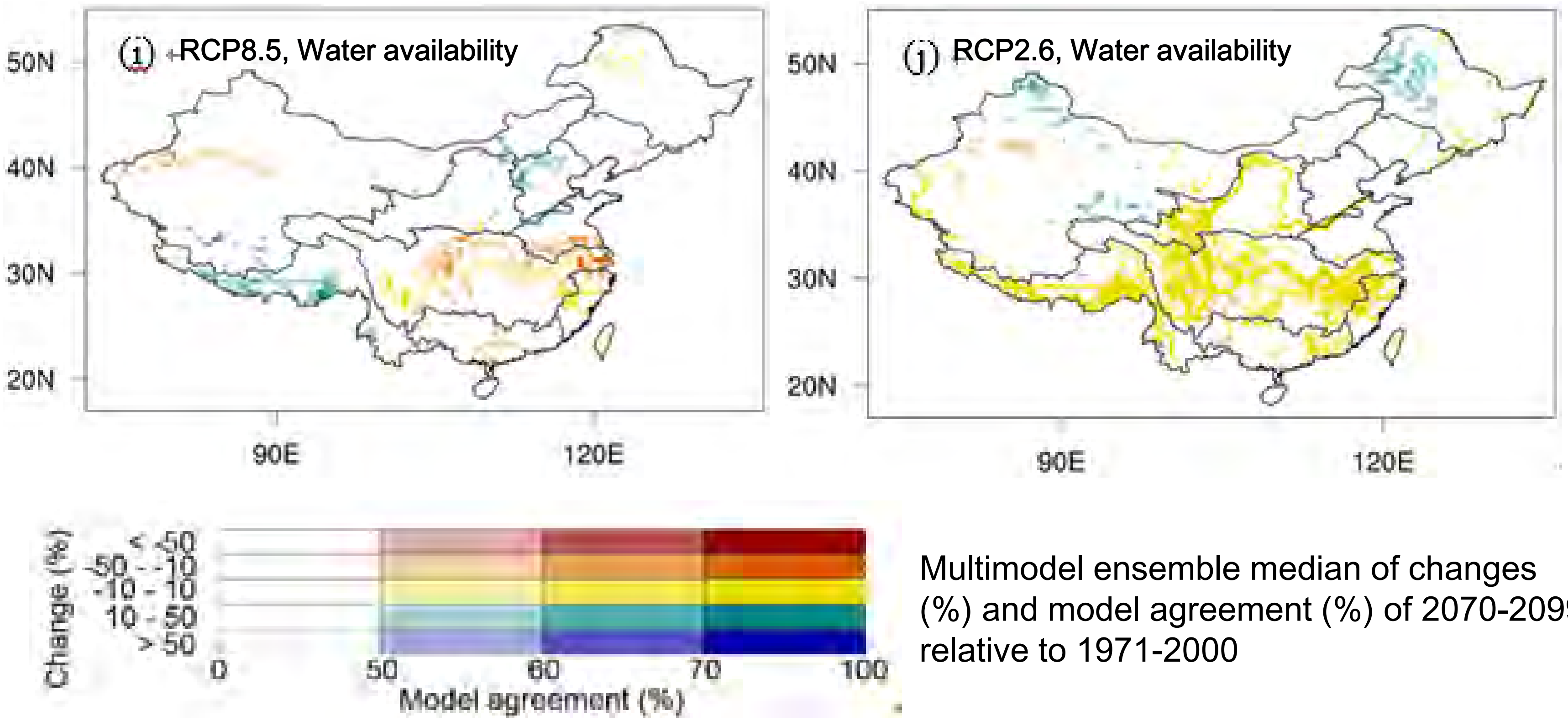
- **Major floods across China generally increase by 10%-50% with acceptable model agreement under both RCP8.5 (to a greater extent) and RCP2.6, especially in the Pearl River, Yangtze River, Yellow River, southeast rivers, southwest rivers and Songhuajiang River. Larger floods (≥20 yrs) increase more than smaller ones.**
- **ISI-MIP simulations of annual maximum discharge seldom reach agreement on the changes in northwest China.**



Multimodel ensemble median of changes (%) and model agreement (%) of 2070-2099 relative to 1971-2000

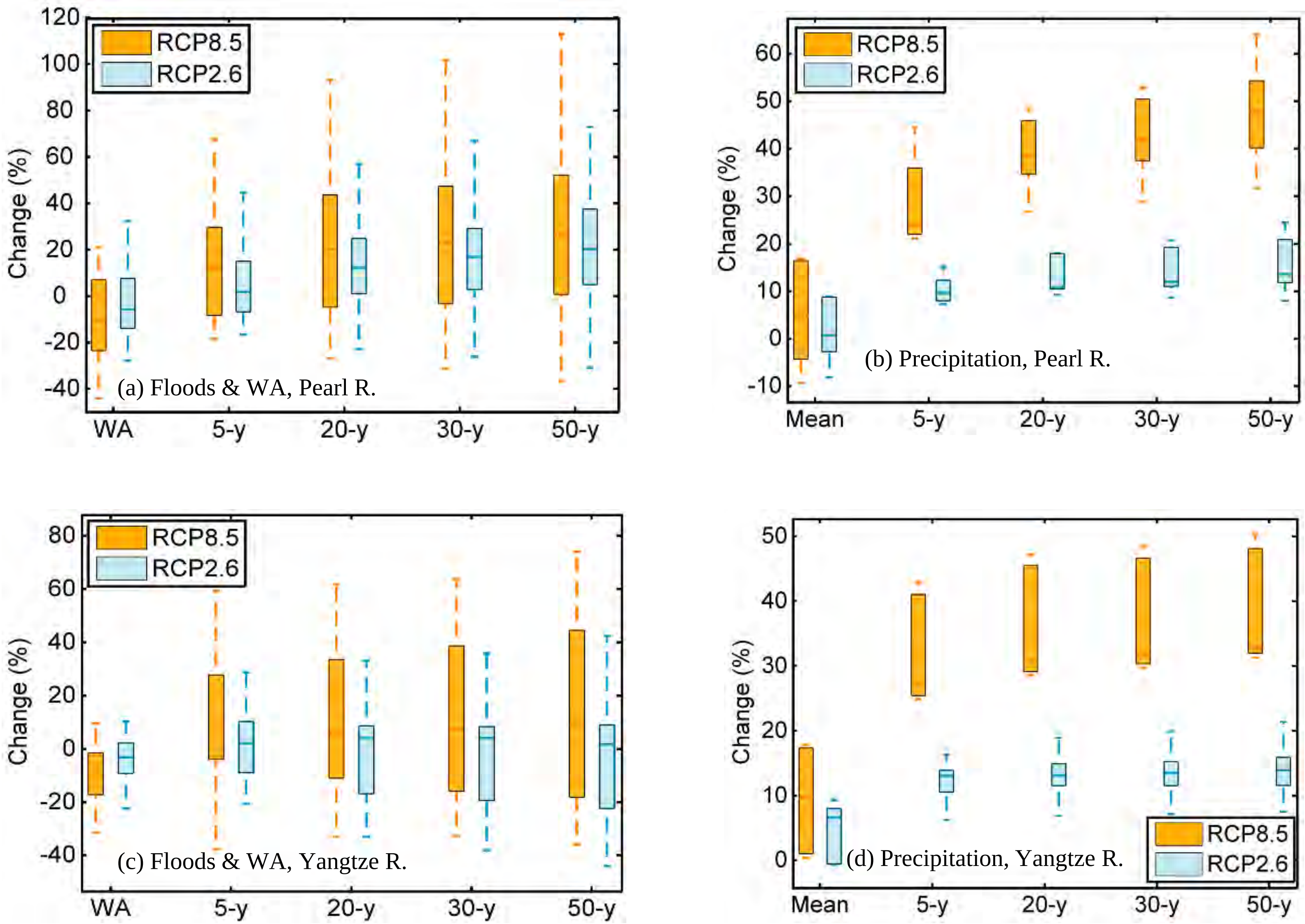
❖ **Water availability decreases under RCP8.5, but changes negligibly under RCP2.6, particularly in the Pearl River and Yangtze River.**

❖ **Generally, compared to flood simulations, the model agreements are lower in water availability projections.**

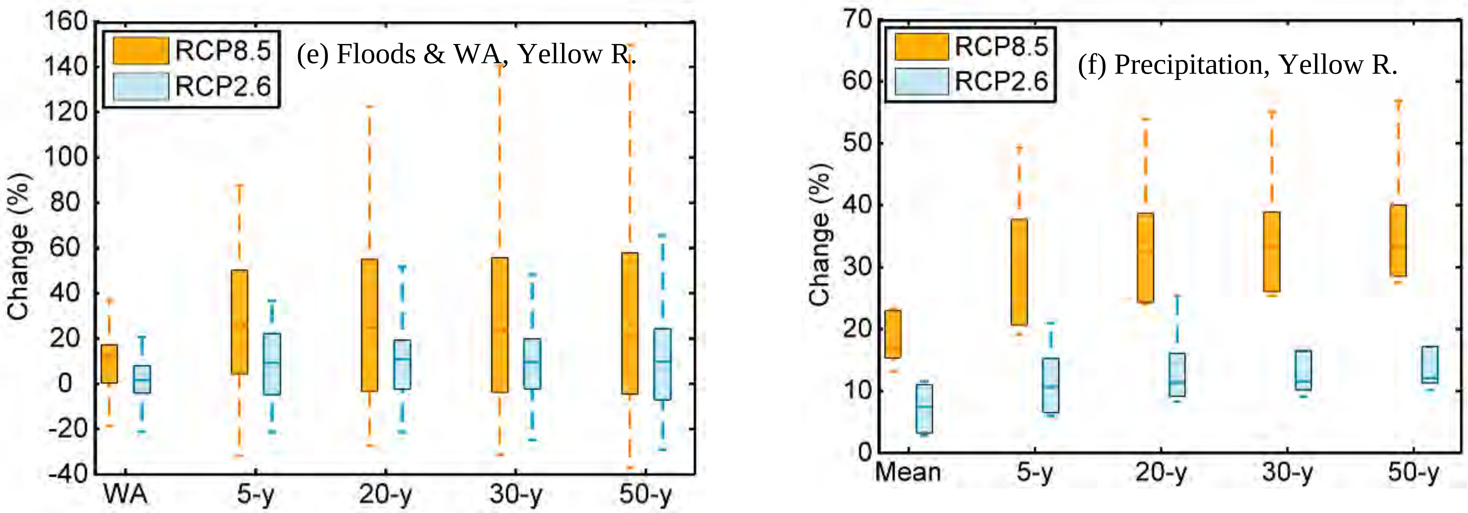


Multimodel ensemble median of changes (%) and model agreement (%) of 2070-2099 relative to 1971-2000

Dominant role of precipitation in changing floods and water availability



Dominant role of precipitation in changing floods and water availability (cont'd)

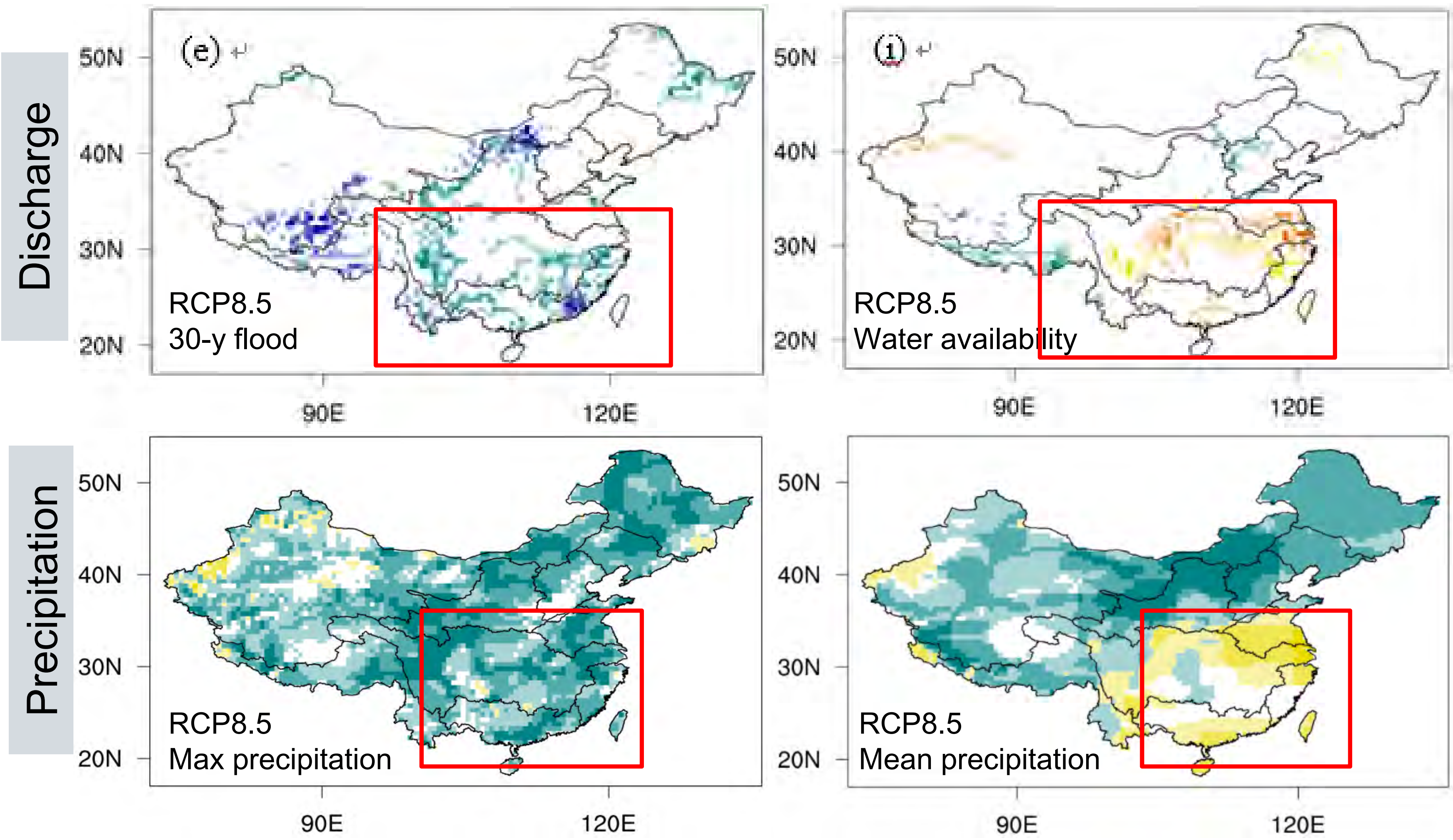


Box-and-whisker plots of change rates of floods and water availability, as well as precipitation mean and extremes in the three major basins

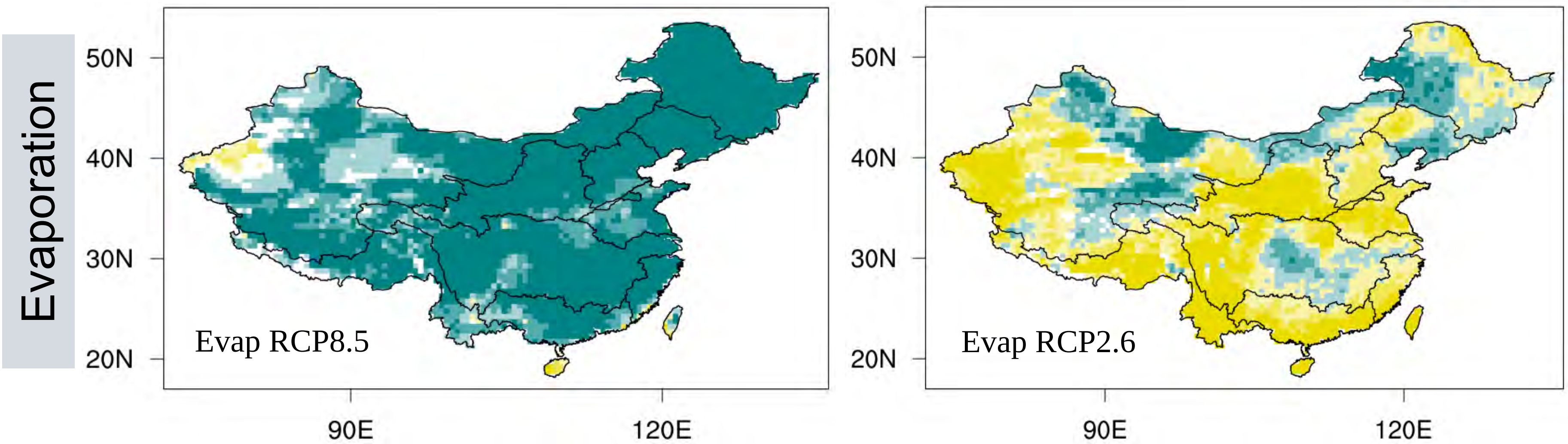
- ❖ Extreme precipitation increases generally, more under RCP8.5 and for longer return periods, but mean precipitation changes negligibly in the Pearl River basin and Yangtze Basin.

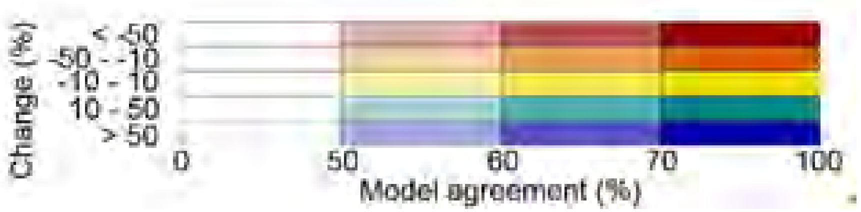
- ❖ Precipitation increases more than floods and water availability, implying the role of evaporation in water balance, especially under RCP8.5.

Intensified floods, but reduced water availability in South China



Global warming will substantially increase ET under RCP8.5



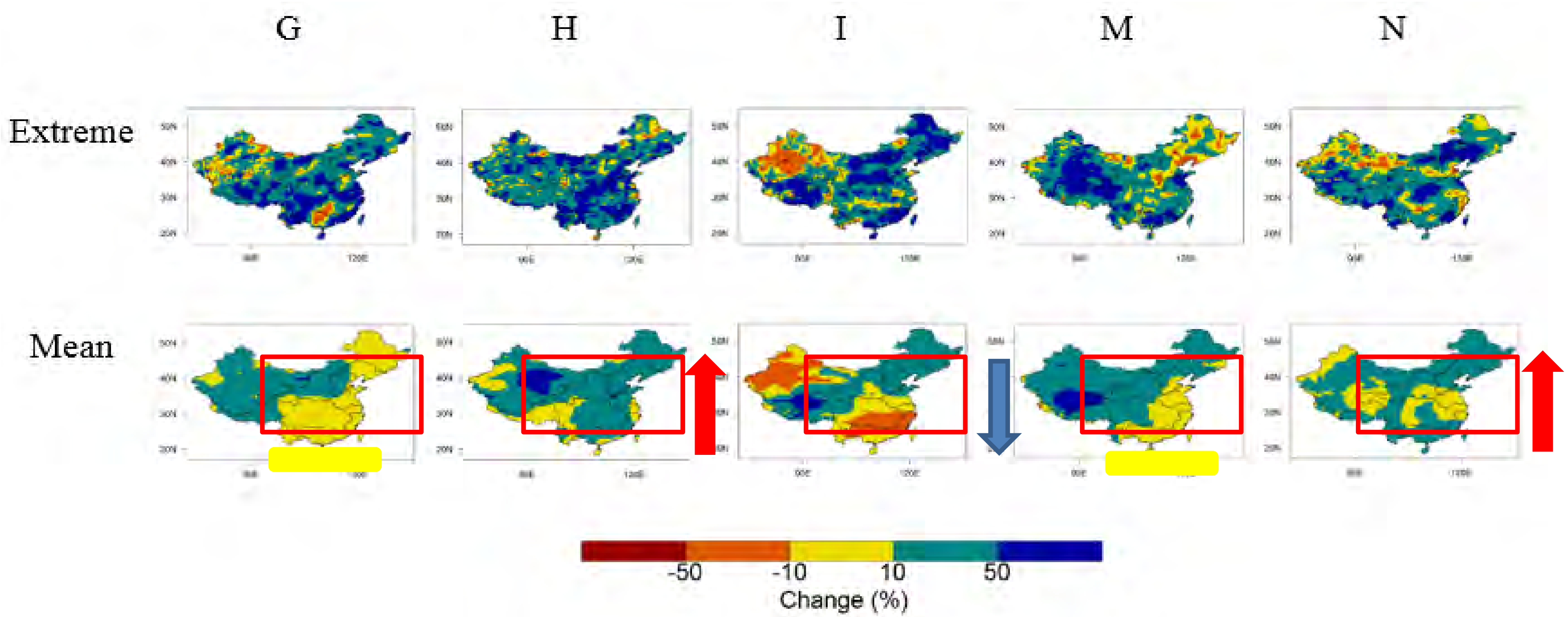


Multimodel ensemble median of changes (%) and model agreement (%) of 2070-2099 relative to 1971-2000

— P = ET ↑ + R ↓

So, reduced water availability!

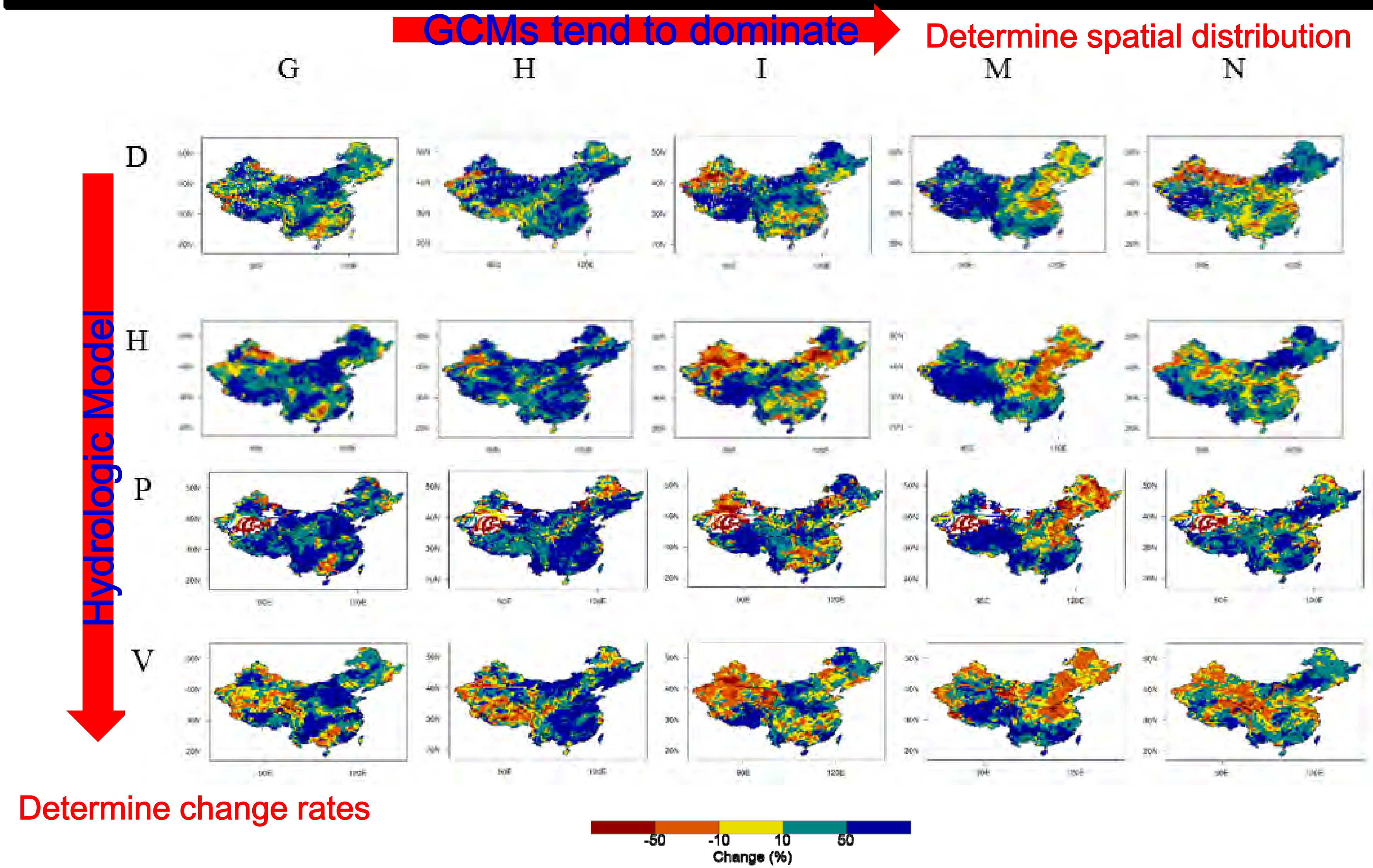
Large uncertainties in precipitation projections among GCMs



Changes (%) of precipitation extreme and mean of different GCMs under RCP8.5

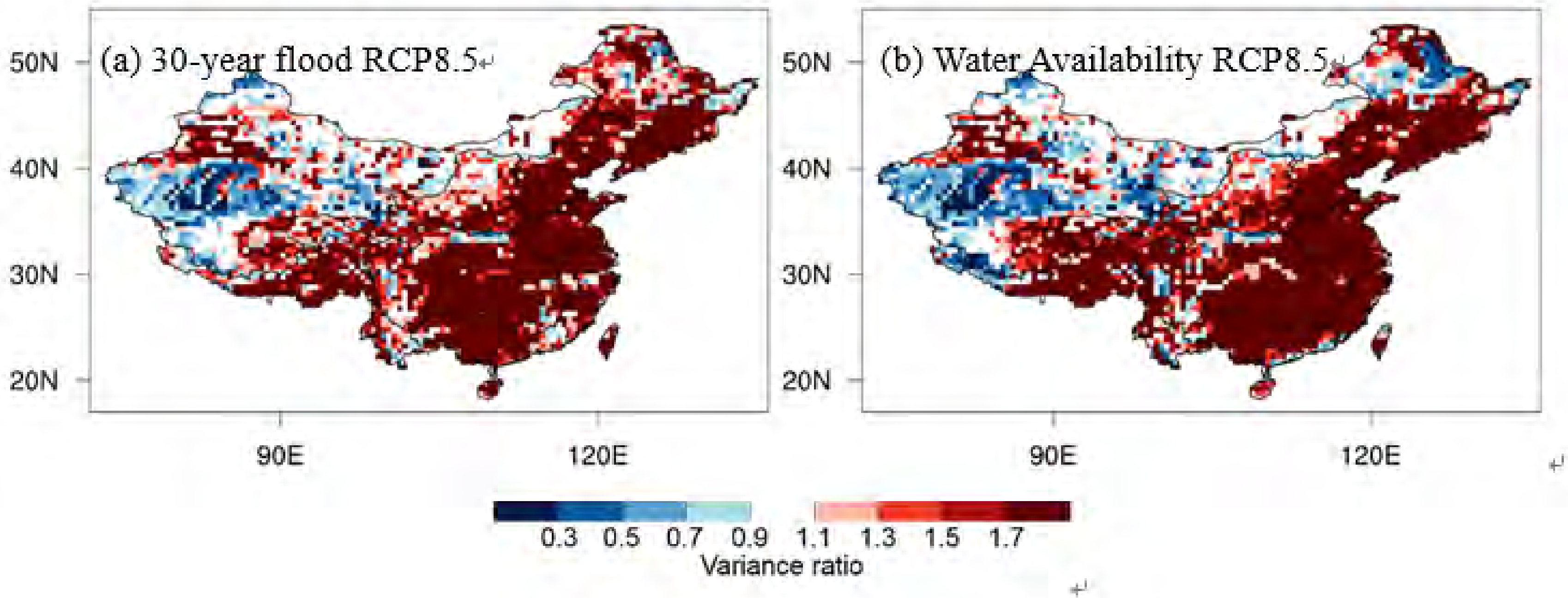
- All GCMs project significant increases in precipitation extremes.
- Projections of mean precipitation vary substantially or even contradict.
- This simple comparison seems to indicate that we can have more confidence in the projection of *precipitation extremes*.

Uncertainties among hydrologic models and GCMs



Changes (%) of floods projected by different GCMs and hydrologic models

Major source of model uncertainties as indicated by the ratio of GCM variance to HM variance: GCM or HM?



Average of 8 GCM variances (each of 8 HMs with 5 GCMs) divided by
Average of 5 HM variances (each of 5 GCMs with 8 HMs)

- GCM variance dominates to varying extents in most parts of the country and such dominance seems to coincide with the humid and semi-humid regions. Interestingly, the boundary generally follows the annual isohyet of 400 mm.
- To the west, blue-colored grid cells (the ratio less than one) do exist in some locations with very dry climate and indicate greater model uncertainties caused by HMs.

Major findings and conclusions

(1) ISI-MIP simulations have certain abilities in modeling floods and water availability under climate change. Multimodel ensemble medians can represent floods and water availability well, but generally tend to underestimate floods and overestimate water availability.

(2) Compared to HMs, GCMs play a more significant role in determining the spatial patterns of changes in floods and water availability. GCM variances dominate the uncertainties of floods and water availability in the humid and semi-humid regions in the eastern China, while HM variances play a more significant role in the arid and semi-arid regions in the northwestern China.

(3) During 2070-2099, floods will increase, but water availability will decrease in south China under RCP8.5, implying that this region may face greater threats from flood hazards but also endure less available water resources which may worsen the conflict between water demand and availability, and also increase the drought risks. In the northern China, the study indicates that floods and water availability both increase. Under RCP2.6, floods increase while water availability changes negligibly across China. Generally, floods in China in the future increase more significantly than water availability. The increase rates of the more extreme floods are higher than those of the less extreme ones.

Major findings and conclusions (cont'd)

(4) Highly intensifying precipitation extremes are the primary reason of significant increase in floods over China in the future. Under RCP8.5 in south China, although precipitation extremes intensify, mean precipitation changes negligibly. The precipitation changes combined with increased evapotranspiration as a result of rising temperature will reduce water availability. In north China, although evapotranspiration increases, the wet tendency of precipitation is found to be even more significant, leading to increase of water availability. Generally, due to the increase of evapotranspiration caused by higher temperature, the changes in floods and water availability are less significant than those in precipitation.

(5) Model agreements for the changes in floods are generally higher than water availability, mainly because of the greater uncertainties associated with the simulated mean precipitation from GCMs. GCMs tend to consistently project significant increase in precipitation extremes over China, but varying changes in mean precipitation especially in the southern China under RCP8.5.

(6) A major limitation of this study is that the changes in vegetation due to changing climate and hydrologic conditions are not taken into consideration in the HMs.

2017年2月4日《信報》

未雨綢繆 以解乾旱與水患

SCMP

BACK PAGE

PREPARE FOR FLOODS, DROUGHT

David Chen Yongqin says Hong Kong must make plans now to cope with the myriad and far-reaching consequences of climate change, which, when it hits in full, may mean not just more frequent extreme weather but also serious water shortages

Last year was the hottest on record – that was the unanimous conclusion of three of the world's top climate experts, the World Meteorological Organisation, the European Union's Copernicus Climate Change Service and Nasa at the end of 2016.

Satellite photos have alarmingly revealed that the Arctic ice cap is shrinking and, recently, that a gigantic ice sheet looks set to break off from Antarctica at any time. These signs show global warming is a fact of life, and various meteorological phenomena in recent years tell us it is already wreaking devastating damage. The debate now is no longer about whether the world is heating up, but how fast the Earth's average temperature is increasing, how that will affect our daily lives, and what we can do about it.

The consequences of global warming are not limited to extreme weather conditions or the increasing frequency and intensity of heat waves and cold spells that the media tends to focus on. Floods and droughts of a destructive scale are likely to be another major menace. Populations along coastal regions or major rivers are likely to be the hardest hit. To understand what could happen to Hong Kong in a hotter Earth, we should look at a study conducted jointly by researchers at the Chinese University of Hong Kong and the Commonwealth Scientific and Industrial Research Organisation, that examined the future changes in floods and water availability across China.

Using proven hydrologic models and past observed data, the study concludes that in the likely scenario of continued growth in greenhouse gas emissions throughout this century, floods brought about by more frequent and heavier rainfall would increase both in number and intensity in southern China, such as in the Pearl River Basin, in the final three decades of the 21st century. The study also finds that, despite the increase in heavy rainfall, the amount of water that can be retained for human consumption would fall, signifying a potential risk of water shortage in the coming decades.

People braving the strong winds in Tsim Sha Tsui as Typhoon Haima hit last year. Photo: Edmond So

> **The debate is no longer about whether the world is heating up, but how fast temperature is increasing**

The findings are quite intuitive. The rise in average temperatures will increase both the rate and amount of moisture evaporating into the atmosphere. With a temperature rise of 1 degree Celsius, the atmosphere is able to hold 7 per cent more water vapour, which would eventually condense and fall back to earth as rain, sleet or hail. Precipitation that falls in heavy torrents will cause widespread floods when rivers and water courses cannot discharge it as quickly as they receive it.

Although the study projects situations over a seemingly distant time horizon, the effects have already emerged. The adverse impact of climate change is being felt now: heavy torrents that had occurred only once every 50 or 100 years in the past are becoming more frequent.

Situated at the tip of the Pearl River Basin, Hong Kong is likely to face the same weather patterns as those projected for other parts of southern China, and is likely be exposed to similar risks of flood and drought. That means our future generations are more likely to suffer both water shortages and deluges from heavy rainstorms.

Instead of frantically looking for remedies only when the impact of global warming becomes impossible to reverse, it is important to implement preventive measures as soon as possible. These efforts should not be restricted to investment in infrastructure. The Hong Kong government should begin to foster closer collaboration with neighbouring mainland cities with which we share common water resources. In recent decades, the Water Services Department has adopted a range of measures to conserve water, control leakage, extend the use of seawater for toilet flushing and has built a desalination plant using reverse-osmosis technology. Meanwhile, the Drainage Services Department has taken on massive infrastructure developments, including construction of storm water storage tanks and tunnels, to improve the city's drainage capabilities.

While the government is moving in the right direction, more forward thinking and planning are needed. Maintaining a stable freshwater supply, for instance, needs more strategic thinking. Given the intense competition for land, extending water catchments or building new reservoirs are impractical. Yet, heavy reliance on the Dongjiang (East River) as our major supply of fresh water may not be sustainable. One major concern is the relative priority Hong Kong would get in receiving water from the Dongjiang compared with other mainland cities in the event of a drought.

It is therefore advisable to construct more desalination plants as a reasonable long-term measure to widen the sources of local water supply.

At the same time, since Hong Kong will continue to rely on the Dongjiang due to cost, resource management and environmental protection, it is important that we try to safeguard the supply in the long term. Guangdong is also aware of the possible risk of water shortages and is already working on plans to divert water from the Xijiang (West River) into the Dongjiang to meet the needs of the eastern parts of the Pearl River Delta. The Hong Kong government should seek to participate in the planning and implementation of this scheme to ensure the city's needs are fully taken into account.

Dr David Chen Yongqin is professor of geography and resource management in the Faculty of Social Science at the Chinese University of Hong Kong

香港因處於珠三角地帶，未來數十年或會面對洪水和乾旱天氣的風險。與其等到全球氣候暖化的惡果到了無法逆轉時才急謀對策，不如未雨綢繆，及早作出預防項目和配套的規劃和協調，以確保在落實「西水東調」計劃和水資源分配下，香港市民的利益可得到充分考慮。

香港中文大學社會科學院地理與資源管理學系教授


THANK YOU
谢 谢！
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The Chinese University of Hong Kong

The University of Hong Kong

Evaluation of socioeconomic droughts under climate changes

Ji CHEN

Department of Civil Engineering

The University of Hong Kong, Hong Kong, China

May 29, 2018

Science of the Total Environment 616–617 (2018) 363–375

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

A new method and a new index for identifying socioeconomic drought events under climate change: A case study of the East River basin in China

Haiyun Shi [a,b], Ji Chen [a,*], Keyi Wang [c], Jun Niu [d,e]

[a] *Department of Civil Engineering, The University of Hong Kong, Hong Kong, China*
[b] *State Key Laboratory of Plateau Ecology and Agriculture, Qinghai University, Xining, Qinghai, China*
[c] *State Key Laboratory of Hydroscience & Engineering, Tsinghua University, Beijing, China*
[d] *Center for Agricultural Water Research in China, China Agricultural University, Beijing, China*
[e] *College of Water Resources & Civil Engineering, China Agricultural University, Beijing, China*

- Shi et al. (2018) proposed a new method, a heuristic method, and a new index, the socioeconomic drought index (SEDI), for identifying and evaluating socioeconomic drought events on different severity levels (i.e., slight, moderate, severe, and extreme) in the context of climate change.
- For historical and future drought analysis, the proposed new method and index are feasible to identify socioeconomic drought events. The results show that a number of socioeconomic drought events (including some extreme ones) may occur in future, and the appropriate reservoir operation can significantly ease such situation.

Background

- **Drought**
  - **A complex natural hazard**
    - **Large areas, long time periods**
    - **Highly destructive effects**
    - **Water supply, agricultural production, ecological environment**

  - **Four categories (American Meteorological Society 2013)**
    - **Meteorological drought: Precipitation**
    - **Hydrological drought: Streamflow**
    - **Agricultural drought: Evapotranspiration**
    - **Socioeconomic drought: Water demands**
      - ✓ **When water resources systems cannot meet water demands due to a weather-related shortfall in water supply**

Background

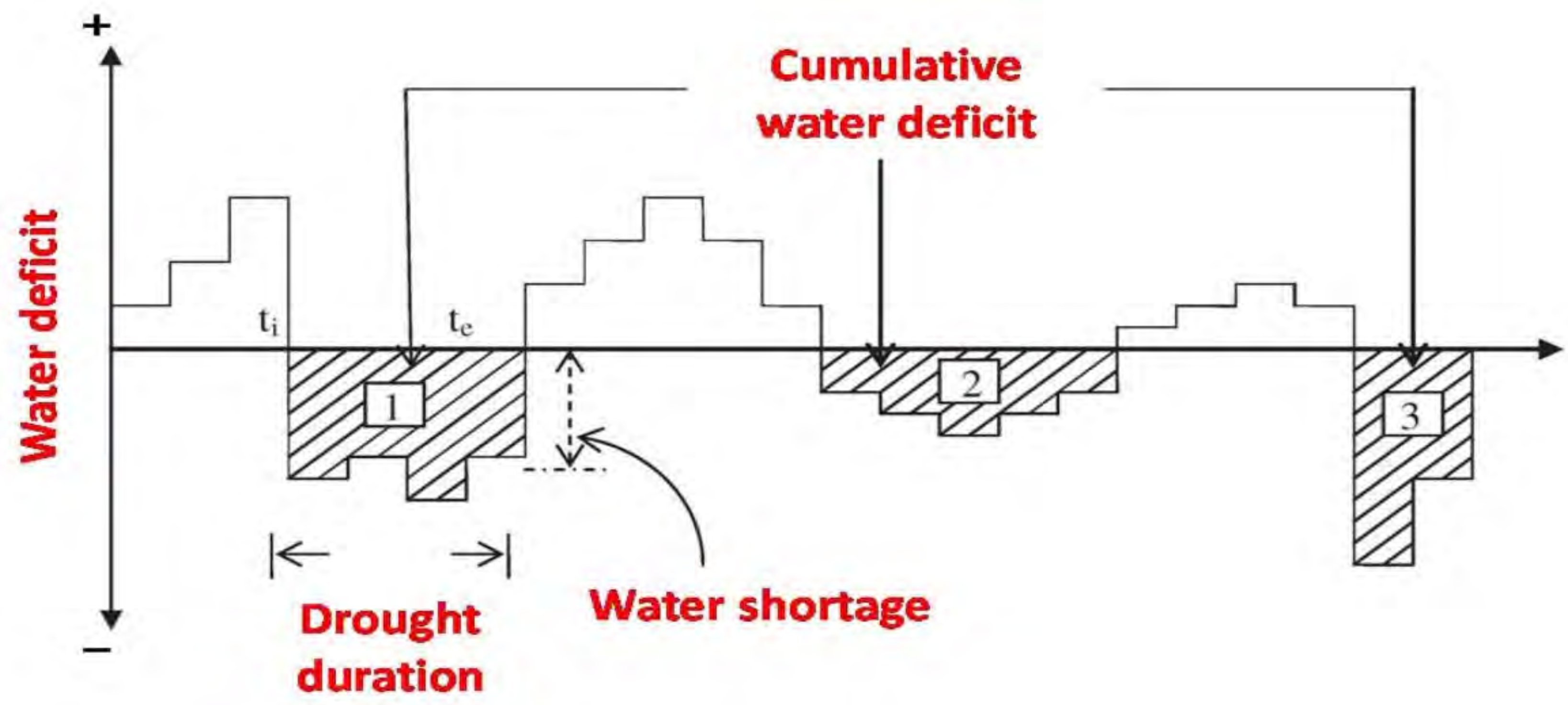
- **Drought indices**
  - **Meteorological drought**
    - **PDSI (Palmer Drought Severity Index)**
    - **SPI (Standardized Precipitation Index)**
    - **SPEI (Standardized Precipitation-Evapotranspiration Index)**
  - **Hydrological drought**
    - **PHDI (Palmer Hydrological Drought Index)**
    - **SWSI (Surface Water Supply Index)**
  - **Agricultural drought**
    - **RWD (Relative Water Deficit)**
    - **VCI (Vegetation Condition Index)**

Background

- **Challenges**
  - **Climate changes**
    - **May cause a dramatic change in hydrological cycle**
  - **Increasing water demand**
    - **Due to continuous population growth, water demand has increased many-fold and will keep increasing in the future**
- **Objective**
  - **To develop a heuristic method and a new index to identify socio-economic drought events**
    - **Considering the gap between water supply and demand**
    - **Using different datasets of future climate change scenarios**
    - **Impact of dam (related reservoir) on drought**

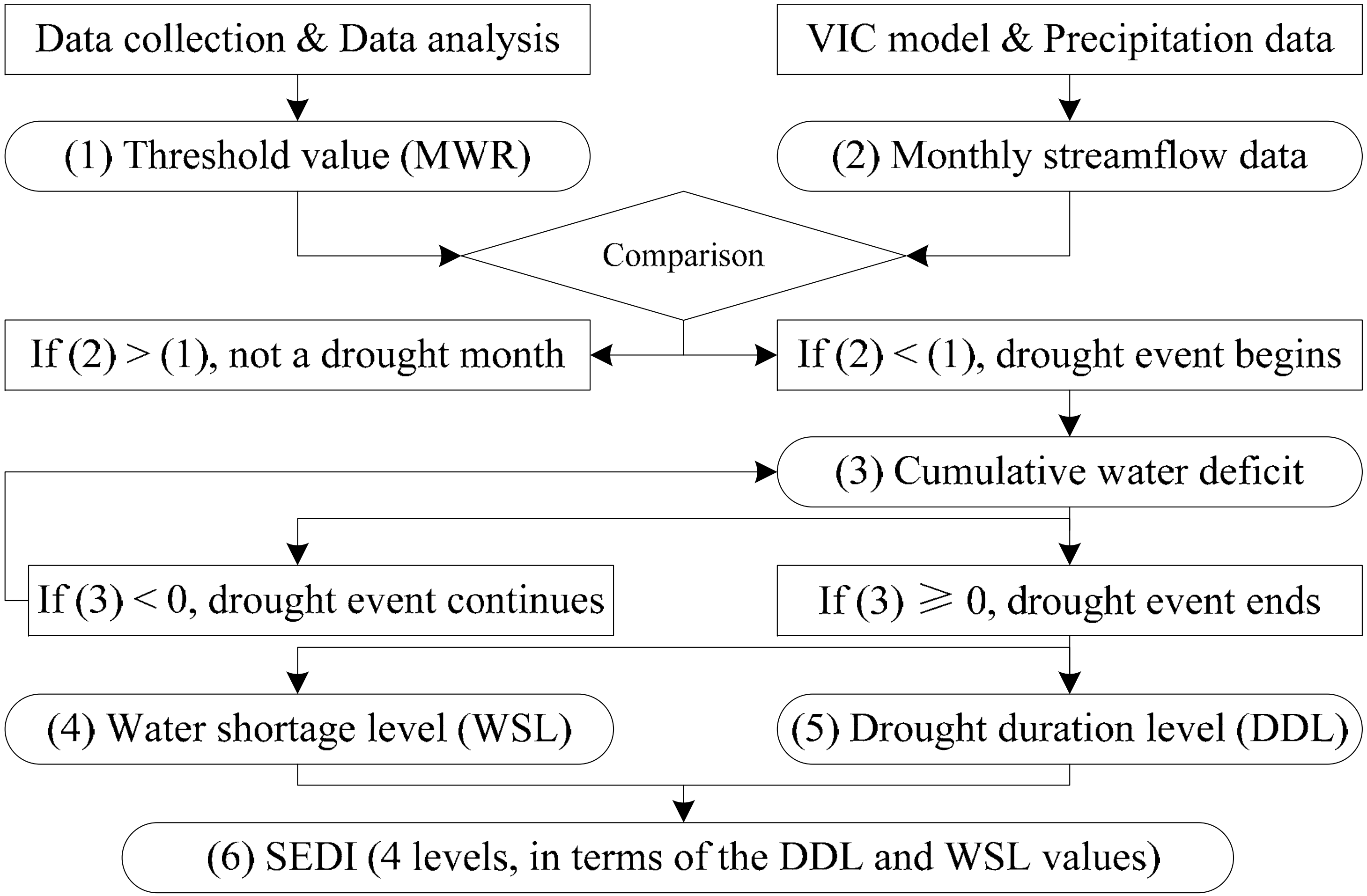
Methodology

- The impacts of both water shortage and drought duration are comprehensively evaluated



Methodology

● Framework



Methodology

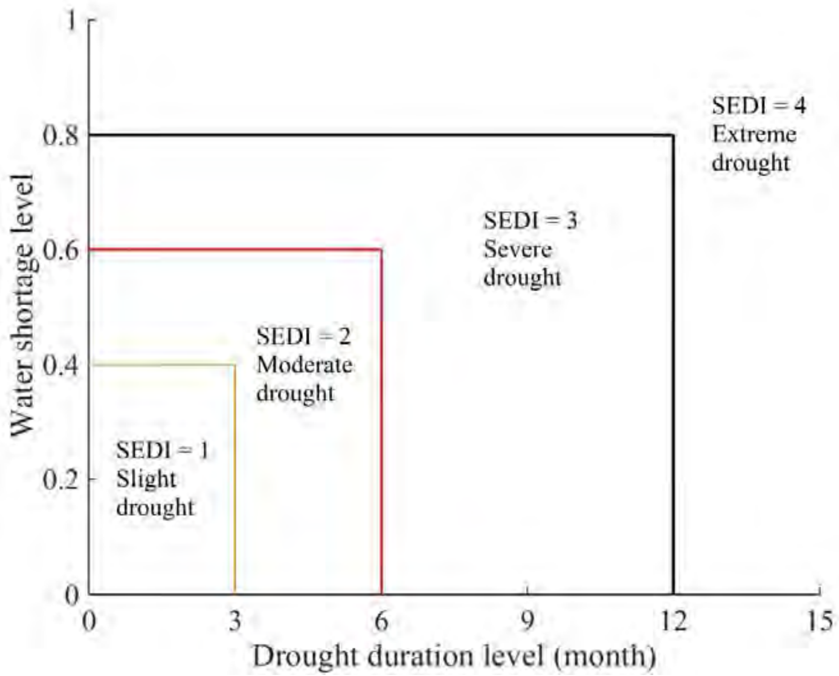
- **The heuristic method and the SEDI**
  - To determine the MWR (minimum in-stream water requirement) value
  - To get the monthly streamflow data (either the observed data or the simulated data from the VIC model)
  - To calculate the monthly difference using the monthly streamflow data minus the MWR, and then to obtain the cumulative water deficit
  - To identify both drought duration (the number of continuous drought months) and water shortage (the largest cumulative water deficit during the drought period)
  - To calculate SEDI through integrating the impacts of water shortage and drought duration, SEDI = max{DDL, WSL}

Methodology

● The heuristic method and the SEDI

Table 1
Definitions of the SEDI based on different levels of water shortage and drought duration.

SEDI		Water shortage level (WSL)		Drought duration level (DDL)	
Value	Definition	Value	Definition	Value	Definition
1	Slight	1	RSP < 40%	1	Quarterly (i.e., 1–3 months)
2	Moderate	2	40% < RSP < 60%	2	Semi-annual (i.e., 4–6 months)
3	Severe	3	60% < RSP < 80%	3	Annual (i.e., 7–12 months)
4	Extreme	4	RSP ≥ 80%	4	>12 months



$$RSP = \frac{Abs(LCWD)}{TRS}$$

RSP: reservoir storage percentage
TRS: typical reservoir storage
LCWD: largest cumulative water deficit
Abs(): function of taking absolute value

Methodology

- **The minimum in-stream water requirement (MWR)**

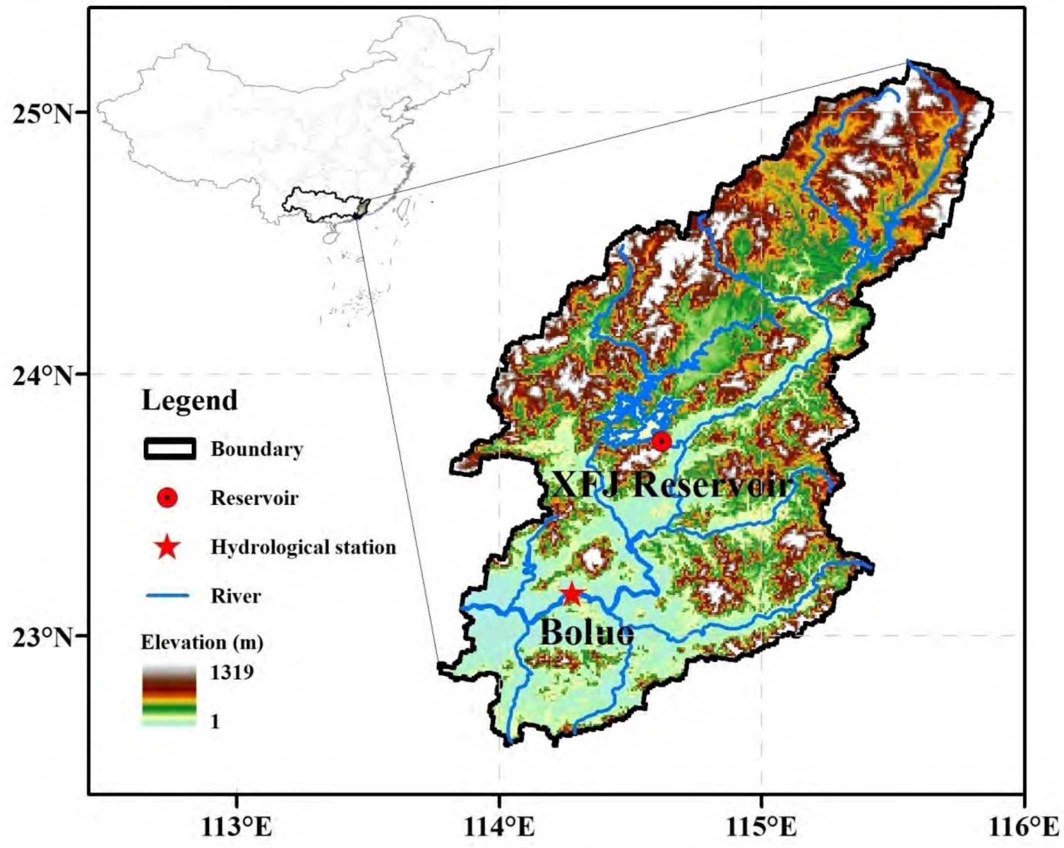
$$MWR = \max\{Q_1, Q_2, Q_3, Q_4\} + Q_s$$

- **Q_1: the minimum streamflow required for maintaining water quality standard**
- **Q_2: the minimum desirable ecological streamflow**
- **Q_3: the minimum streamflow for navigation**
- **Q_4: the minimum streamflow for arresting seawater intrusion into the estuary**
- **Q_s: the pumping rate for water supply (Wu and Chen 2013)**

➢ **Note:**
- The reasonable threshold value for the utilization ratio of water resources of a river is 30%
- The Q_s value should better not be larger than 30% of river runoff

Study area and research data

- **Study area**
  - **East River basin**
    - A sub-basin of the Pearl River basin
    - Originates in Jiangxi Province
    - Length of mainstem: 562 km
    - Drainage area: 35340 km^2
    - Long-term annual average runoff: 23.8 km^3

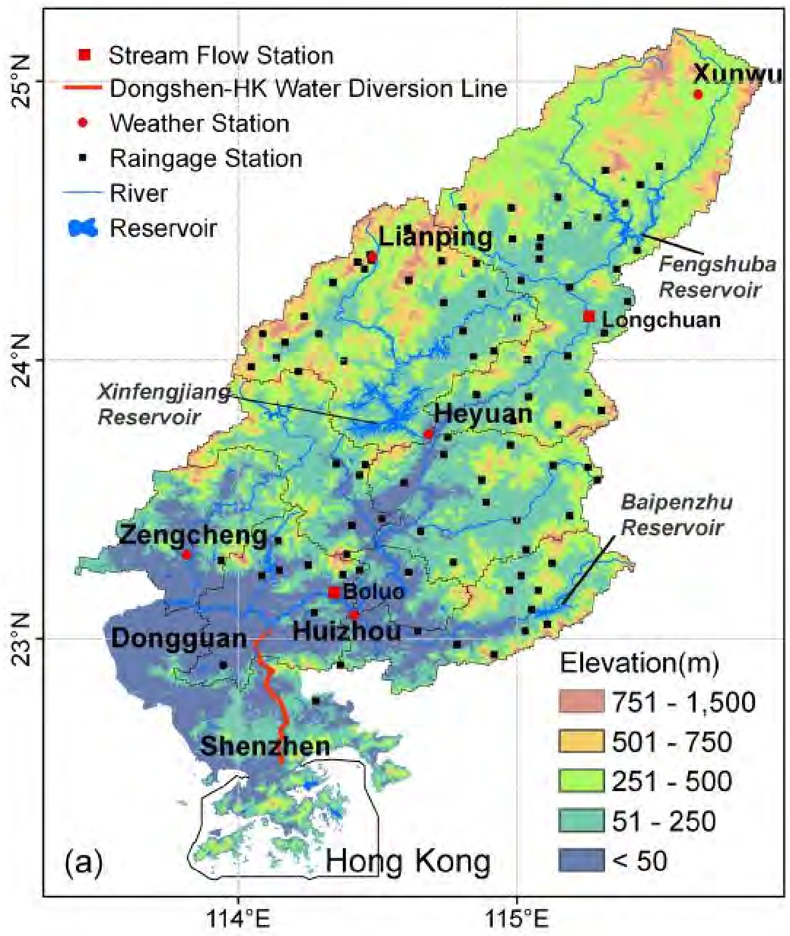


Study area and research data

● Study area

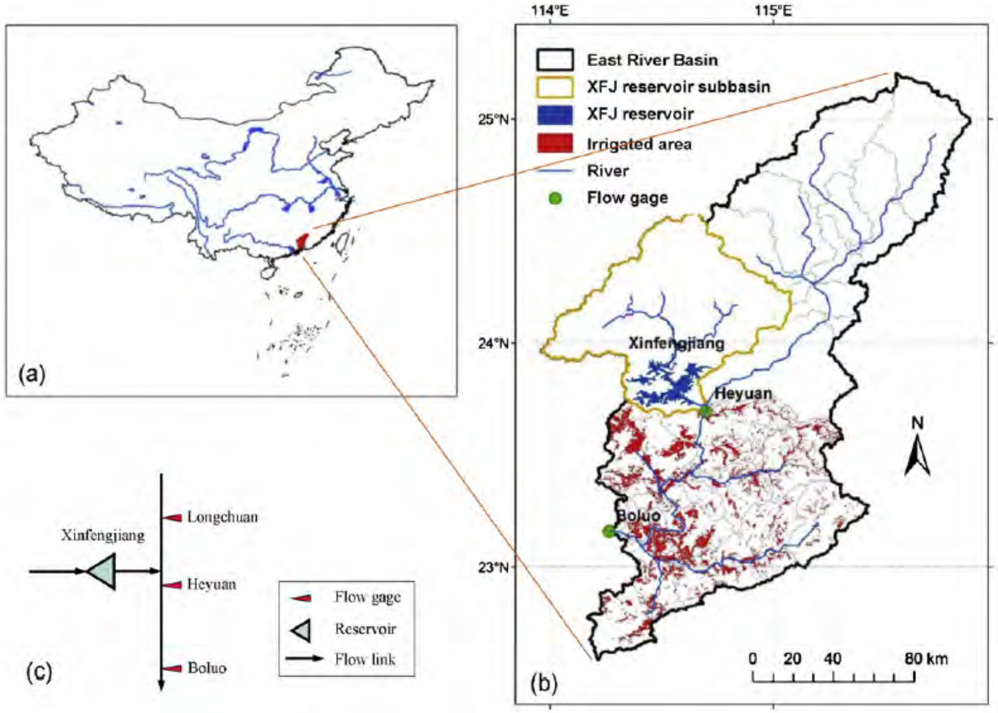
➢ East River basin

- Total Storage capacity of reservoirs: 18.20 billion m^3
- Cities and regions using the East River water:
  - ✓ HY (Heyuan)
  - ✓ HZ (Huizhou)
  - ✓ DG (Dongguan)
  - ✓ GZ (Guangzhou)
  - ✓ SZ (Shenzhen)
  - ✓ HK (Hong Kong)



Study area and research data

- **Xingfengjiang Reservoir**
  - Multiyear, multipurpose
    - flood control, hydropower generation, irrigation, industrial and domestic water supplies
  - Control drainage area
    - 5740 km^2
  - Annual average inflow
    - 6.17 km^3/yr
  - Storage capacity
    - 13.9 km^3
  - Turbine capacity
    - 302 MW



Characteristic water levels and associated storage of the Xinfengjiang reservoir.

Time period	Elevation of water level (m)	Storage (km^3)
Apr 1–Jun 30 (the first half of flood season)	114 (Flood control level)	10.05
Jul 1–Sep 30 (the second half of flood season)	115 (Flood control level)	10.42
Other months (Non-flood season)	116 (Normal pool water level)	10.80

Study area and research data

- Xinfengjiang Dam (concrete gravity dam)
  - Height 124 m, Length 440 m
  - Year of completion: 1962
  - Concrete amount: 1.06 million m^3
- Investment
  - 0.22 billion RMB Yuan (in 1950s)
- Benefit from this project
  - **Annual electricity production**: 9.44×10^8 kW·h
  - **Flood control**: floods in the East River basin are well controlled

    For example, levee failure occurred in the downstream of the Boluo station when there was a once-in-a-century flood in 1959; in contrast, this region was safe when there was another similar flood in 1966

Study area and research data

- **Data**
  - **Precipitation data**
    - **52 sets of climate scenarios**
    - **Observed monthly gauge data during 1952-2000**
  - **Streamflow data**
    - **Simulated with precipitation data using the VIC (Variable Infiltration Capacity) model**
    - **Observed monthly data recorded at the Boluo station during 1954-1988**

Data source (Climate Model)	GHG Emission Scenarios	Horizontal Resolution	Period
16 AR4 GCMs (bccr_bcm2_0.1, cccma_cgcm3_1.1, cnrm_cm3.1, csiro_mk3_0.1, gfdl_cm2_0.1, gfdl_cm2_1.1, giss_model_e_r.1/2, inmcm3_0.1, ipsl_cm4.1, miroc3_2_medres.1, miub_echo_g.1, mpi_echam5.1, mri_cgcm2_3_2a.1, ncar_ccsm3_0.1, ncar_pcm1.1/2, ukmo_hadcm3.1)	SRES A2/A1B/B1	0.5°×0.5°	1951-2099
1 AR5 GCM (HadGEM2-ES)	RCP 2.6/4.5/6.0/8.5	0.5°×0.5°	2000-2099

Results and discussion

- **The MWR value of the East River basin**
  - **The estimated values of Q_1, Q_2, Q_3 and Q_4 at the Boluo station were 317, 230, 210 and 150 m^3/s in 2010 (Wu et al. 2001; Lee et al. 2007)**
  - **Lee et al. (2007) also pointed out that the estimated value of Q_s was 150 m^3/s in 2010**
  - **Water demand would increase along with population growth in the future (Chen et al. 2016), leading to the change of the Q_s value, as well as the MWR value**
  - **Chen et al. (2015) projected the future water demand in the East River basin**
  - **The maximum Q_s value would be 176 m^3/s in 2070, ~ 23.3% of river runoff, <30%**

Results and discussion

- A five-stage water demand model (WDP)

STAGE	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Water Demand	Low Level No Increase	Low Level Slow Increase	Rapid Increase	Stabilized Water Demand	Slow Decrease Until Stable
Economy Level	Least Developed	Less Developed	Fast Developing	Developed	Highly Developed
S Value	< 1,000	1,000~3,000	3,000~ 15,000	15,000~ 45,000	> 45,000

Results and discussion

- **Validation and Confirmation**

Example: Hong Kong

- **Per capita PPP GDP reaches 3,000 GKDs in 1976**
- **Per capita PPP GDP reaches 15,000 GKDs in 1991**
- **Water demand stages since 1950:**
  - ❖ **1950-1976: stage 1 & 2, increases slowly**
  - ❖ **1977-1991: stage 3, increases rapidly and nearly linearly with time**
  - ❖ **1992-now: stage 4, per capita water consumption decreases, annual water consumption keeps increasing due to fast increasing trend of population**

Agree with the proposed model

Results and discussion

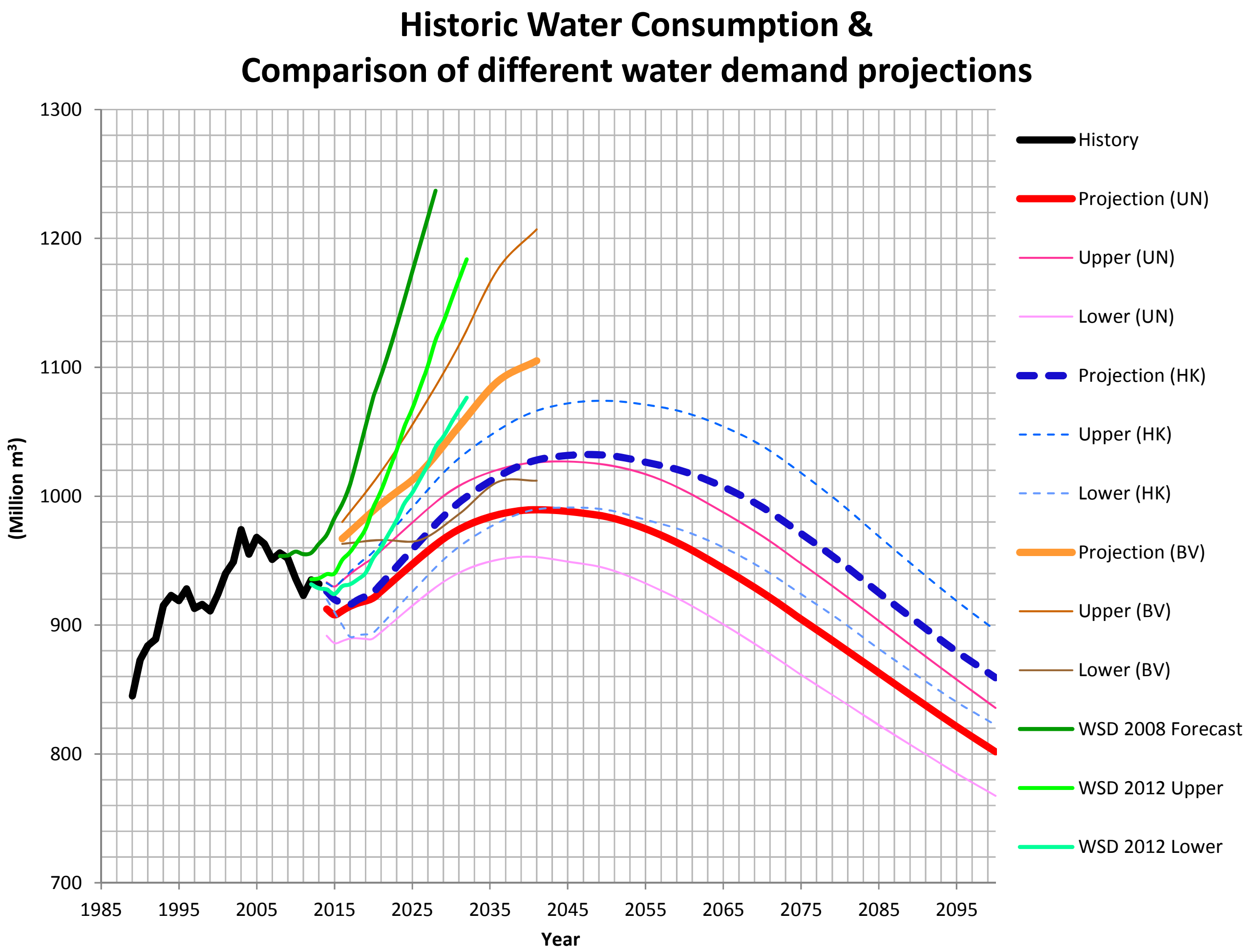
- **Applications of the Model**

Example: Hong Kong

- **Per capita PPP GDP is expected to reach 45,000 GKDs around year 2040**
- **Per capita water demand projection:**
  - ❖ **Before 2040: stage 4, decreases slowly**
  - ❖ **2041-2100: stage 5, decreases slowly until stable level**
- **Annual water demand projection (consider per capita water demand & population growth):**
  - ❖ **Before 2040: stage 4, increases slowly due to fast increasing population**
  - ❖ **2041-2100: stage 5, decreases slowly until stable level**

Results and discussion

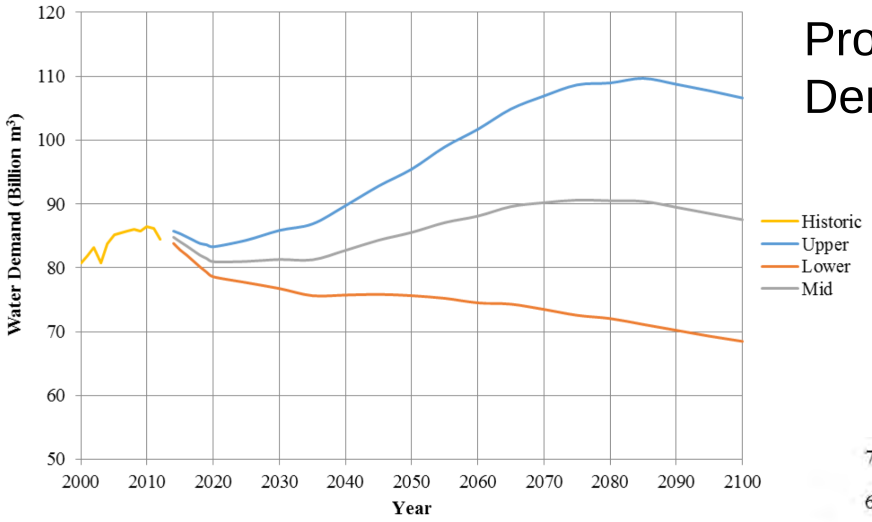
- **Applications of the Model**



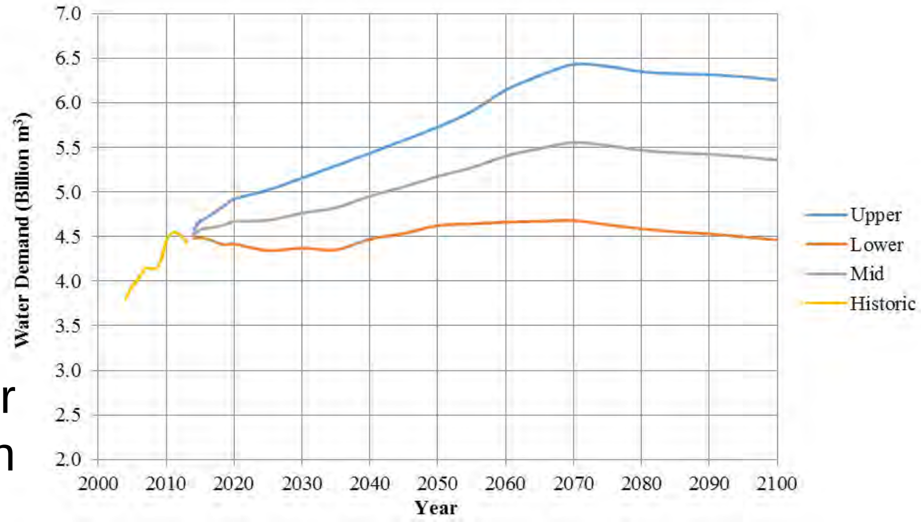
The historical water consumption and the comparison of water demand projection for Hong Kong from different methods, and sources

Results and discussion

- **Applications of the Model**



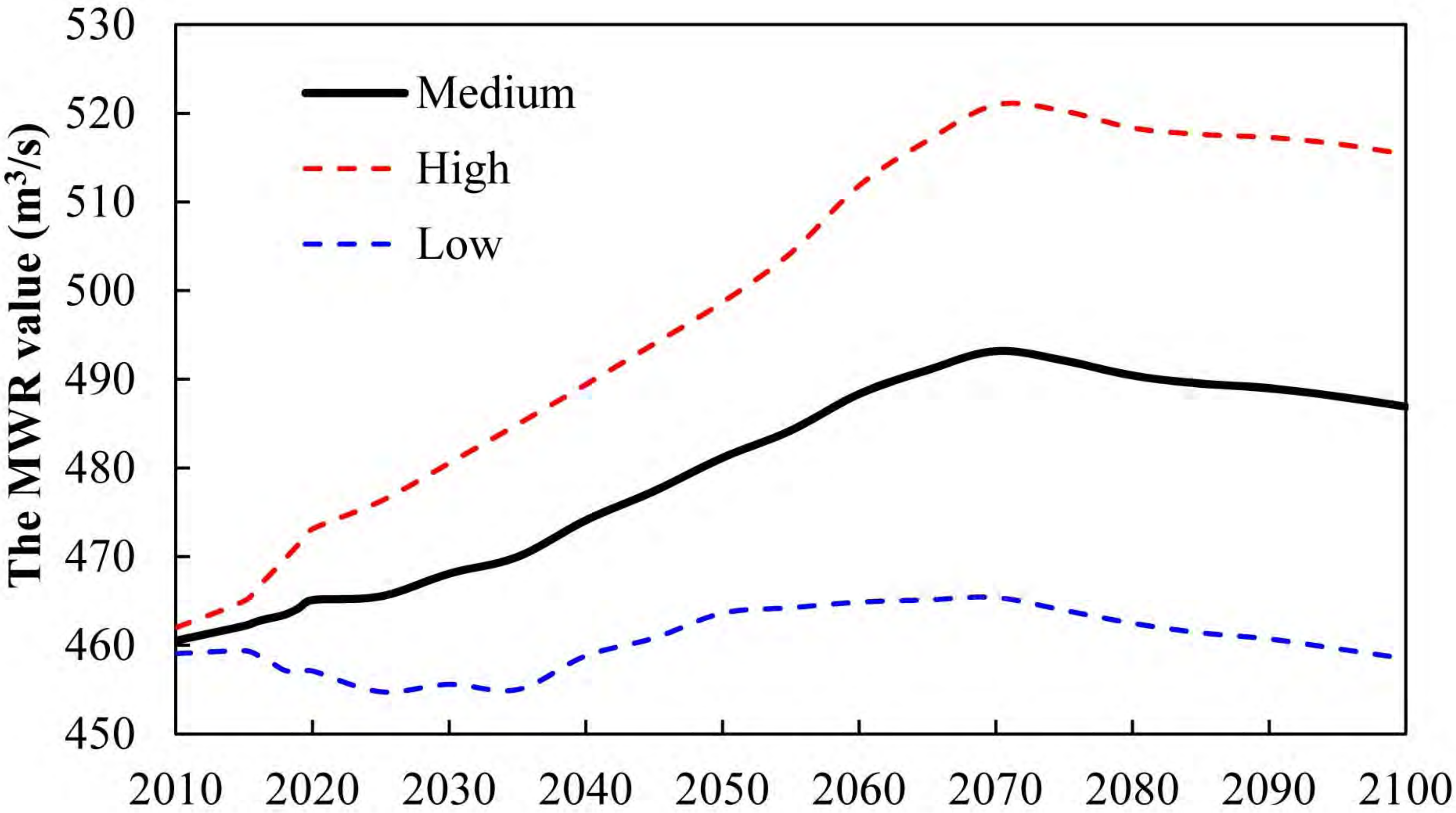
Projected Annual Total Water Demand in the Pearl River basin



Projected Annual Total Water Demand in the East River basin

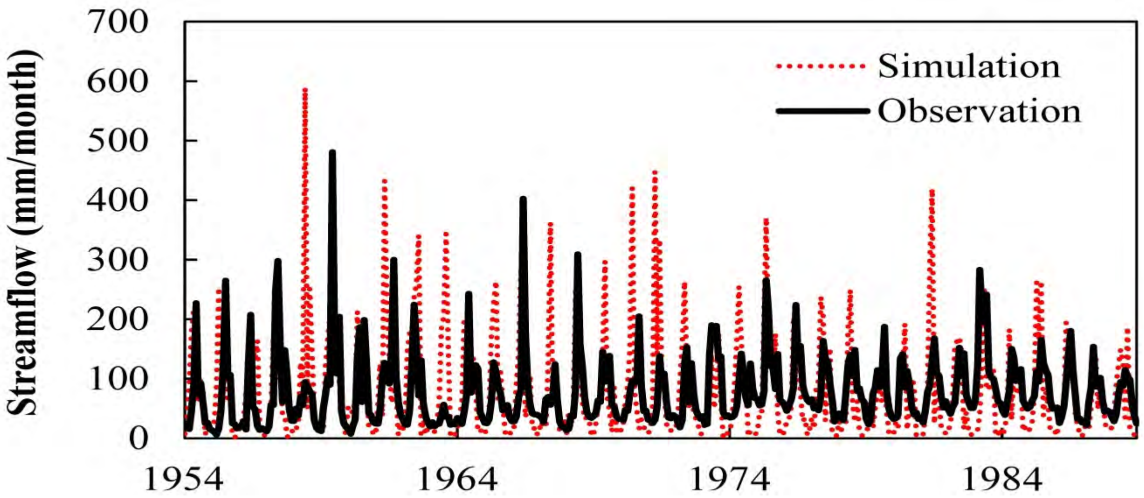
Results and discussion

- **The projected MWR value of the East River basin**



Results and discussion

- **Historical drought analysis**
  - **For the observed monthly streamflow data**
    - **SEDI = 4 (an extreme drought)**
    - **Started in December 1962 and ended in May 1964**
  - **For the simulated monthly streamflow data**
    - **SEDI = 3 (a severe drought)**
    - **Started in September 1962 and ended in May 1963**



The historical observations were basically covered by the simulated monthly streamflow data

Results and discussion

- **Future drought analysis**
  - **Trend analysis of the simulated streamflow in future**

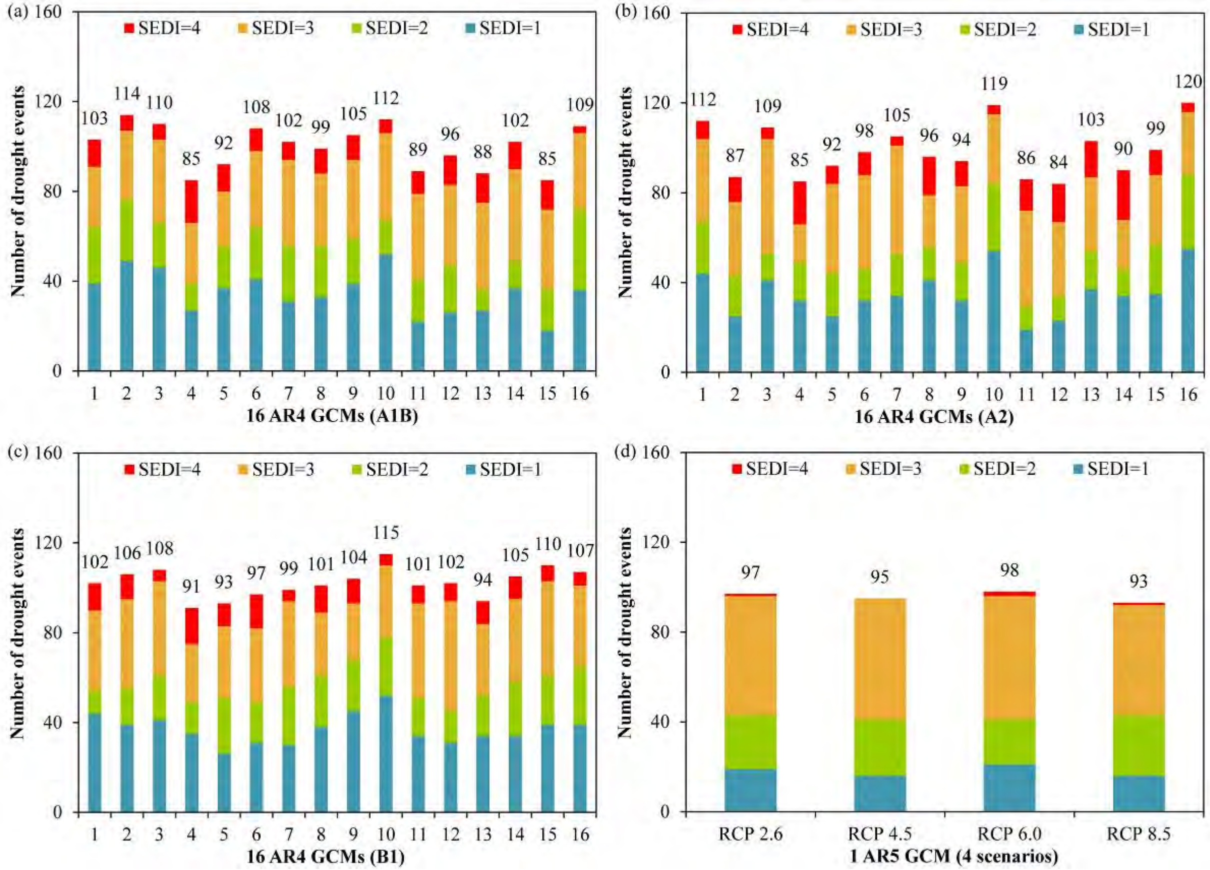
Table 3
The slopes (mm/year) of the simulated streamflow at the Boluo station during 2020–2099 for each of the 52 datasets. Note: p is the significance level.

AR4 scenario	A1B	A2	B1
1. bccr_bcm2_0.1	0.43 ($p > 0.1$)	0.11 ($p > 0.1$)	1.85 ($p > 0.1$)
2. ncar_ccsm3_0.1	2.57 ($p > 0.1$)	4.06 ($\mathbf{p < 0.05}$)	1.65 ($p > 0.1$)
3. cccma_cgcm3_1.1	1.58 ($p > 0.1$)	0.03 ($p > 0.1$)	0.51 ($p > 0.1$)
4. cnrm_cm3.1	2.56 ($\mathbf{p < 0.1}$)	2.02 ($p > 0.1$)	2.29 ($p > 0.1$)
5. csiro_mk3_0.1	−1.72 ($p > 0.1$)	−2.33 ($p > 0.1$)	0.49 ($p > 0.1$)
6. mpi_echam5.1	−2.77 ($\mathbf{p < 0.1}$)	0.29 ($p > 0.1$)	0.27 ($p > 0.1$)
7. miub_echo_g.1	3.38 ($\mathbf{p < 0.05}$)	1.51 ($p > 0.1$)	1.69 ($p > 0.1$)
8. gfdl_cm2_0.1	5.33 ($\mathbf{p < 0.01}$)	1.08 ($p > 0.1$)	3.89 ($\mathbf{p < 0.05}$)
9. gfdl_cm2_1.1	0.44 ($p > 0.1$)	3.03 ($\mathbf{p < 0.1}$)	4.02 ($\mathbf{p < 0.05}$)
10. giss_model_e_r.1/2	3.55 ($\mathbf{p < 0.1}$)	4.28 ($\mathbf{p < 0.05}$)	1.97 ($p > 0.1$)
11. inmcm3_0.1	3.73 ($\mathbf{p < 0.1}$)	5.12 ($\mathbf{p < 0.05}$)	−0.71 ($p > 0.1$)
12. ipsl_cm4.1	−2.22 ($p > 0.1$)	2.12 ($p > 0.1$)	3.27 ($\mathbf{p < 0.05}$)
13. miroc3_2_medres.1	−2.45 ($p > 0.1$)	−0.03 ($p > 0.1$)	0.25 ($p > 0.1$)
14. mri_cgcm2_3_2a.1	3.04 ($\mathbf{p < 0.05}$)	2.80 ($\mathbf{p < 0.1}$)	5.95 ($\mathbf{p < 0.01}$)
15. ncar_pcm1.1/2	2.45 ($p > 0.1$)	−0.39 ($p > 0.1$)	3.08 ($\mathbf{p < 0.1}$)
16. ukmo_hadcm3.1	6.09 ($\mathbf{p < 0.01}$)	6.75 ($\mathbf{p < 0.01}$)	11.02 ($\mathbf{p < 0.01}$)

AR5 scenario	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
17. HadGEM2-ES	2.04 ($\mathbf{p < 0.1}$)	1.24 ($p > 0.1$)	2.63 ($\mathbf{p < 0.05}$)	3.24 ($\mathbf{p < 0.05}$)

Results and discussion

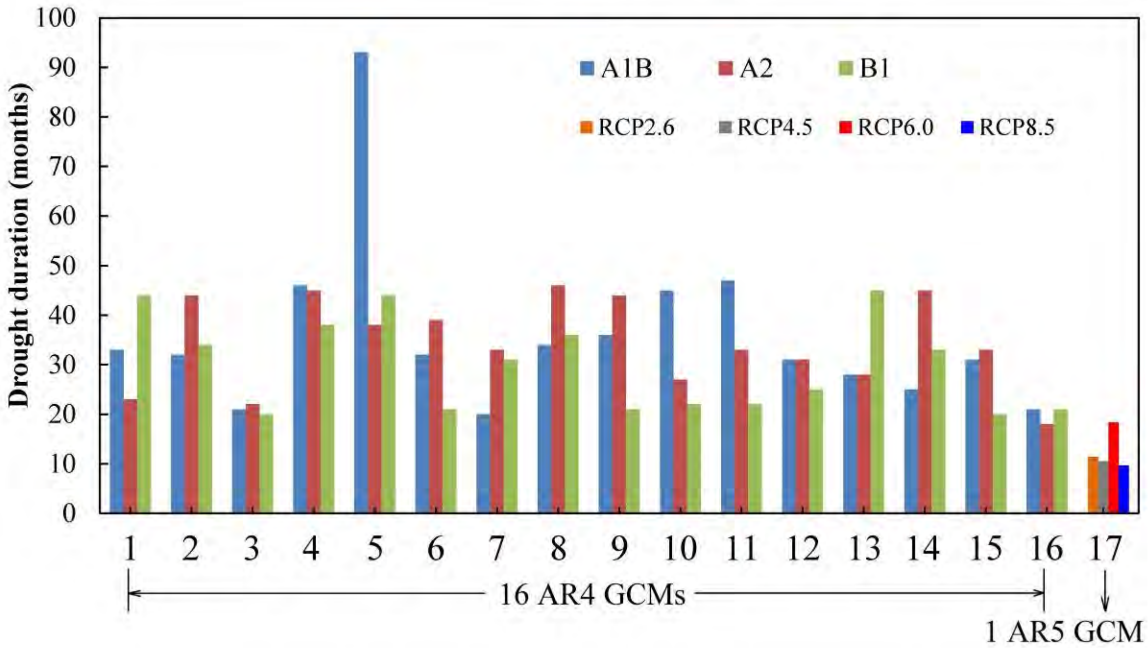
- **Future drought analysis**
  - **The numbers of socioeconomic drought events with different SEDI values for 52 datasets**



Results and discussion

● Future drought analysis

➢ **The socioeconomic drought event with the longest drought duration in future is identified for each of the 52datasets**



➢ **Mean value**

- **AR4: 33 months**
- **AR5: 14 months**
- **Compared to AR4 datasets, AR5 datasets estimated future precipitation influenced by climate change with a more optimistic view**

Results and discussion

- **Future drought analysis**
  - **For the water shortage which is also a crucial factor, the largest RSP value under each of the 52 datasets is computed**

Table 4
The largest RSP value during 2020–2099 for each of the 52 datasets.

AR4 scenario		A1B		A2	B1
1. bccr_bcm2_0.1		1.48		2.04	1.36
2. ncar_ccsm3_0.1		1.38		2.26	1.83
3. cccma_cgcm3_1.1		1.07		1.64	1.40
4. cnrm_cm3.1		2.85		2.39	1.60
5. csiro_mk3_0.1		3.05		2.22	1.81
6. mpi_echam5.1		1.80		2.26	1.02
7. miub_echo_g.1		0.91		2.07	1.27
8. gfdl_cm2_0.1		1.48		1.93	2.03
9. gfdl_cm2_1.1		1.59		2.05	1.34
10. giss_model_e_r.1/2		1.63		1.39	1.14
11. inmcm3_0.1		1.99		1.99	1.74
12. ipsl_cm4.1		1.17		1.36	1.40
13. miroc3_2_medres.1		1.49		1.99	2.53
14. mri_cgcm2_3_2a.1		1.55		2.00	1.57
15. ncar_pcm1.1/2		1.32		1.72	0.91
16. ukmo_hadcm3.1		1.11		0.94	0.93
Mean of the 16 AR4 GCMs		1.62		1.89	1.49
AR5 scenario	RCP 2.6		RCP 4.5	RCP 6.0	RCP 8.5
17. HadGEM2-ES	0.69		0.77	0.82	0.86

Results and discussion

- **Future drought analysis**
  - **The number of socioeconomic drought events with either longer duration or larger RSP value than the 1963 drought event identified from the simulated streamflow data during 2020-2099 for each of the 52 datasets**

AR4 scenario	A1B	A2	B1
1. bccr_bcm2_0.1	29 (28%)	27 (24%)	35 (34%)
2. ncar_ccsm3_0.1	28 (25%)	32 (37%)	32 (30%)
3. cccma_cgcm3_1.1	28 (25%)	30 (28%)	22 (20%)
4. cnrm_cm3.1	38 (45%)	29 (34%)	31 (34%)
5. csiro_mk3_0.1	29 (32%)	34 (37%)	31 (33%)
6. mpi_echam5.1	33 (31%)	35 (36%)	37 (38%)
7. miub_echo_g.1	32 (31%)	33 (31%)	28 (28%)
8. gfdl_cm2_0.1	33 (33%)	31 (32%)	26 (26%)
9. gfdl_cm2_1.1	33 (31%)	32 (34%)	26 (25%)
10. giss_model_e_r.1/2	27 (24%)	18 (15%)	25 (22%)
11. inmcm3_0.1	33 (37%)	39 (45%)	39 (39%)
12. ipsl_cm4.1	31 (32%)	35 (42%)	38 (37%)
13. miroc3_2_medres.1	34 (39%)	33 (32%)	27 (29%)
14. mri_cgcm2_3_2a.1	39 (38%)	36 (40%)	33 (31%)
15. ncar_pcm1.1/2	32 (38%)	31 (31%)	30 (27%)
16. ukmo_hadcm3.1	16 (15%)	19 (16%)	27 (25%)
Mean of the 16 AR4 GCMs	31 (31%)	31 (32%)	30 (30%)

AR5 scenario	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
17. HadGEM2-ES	7 (7%)	7 (7%)	9 (9%)	11 (12%)

Results and discussion

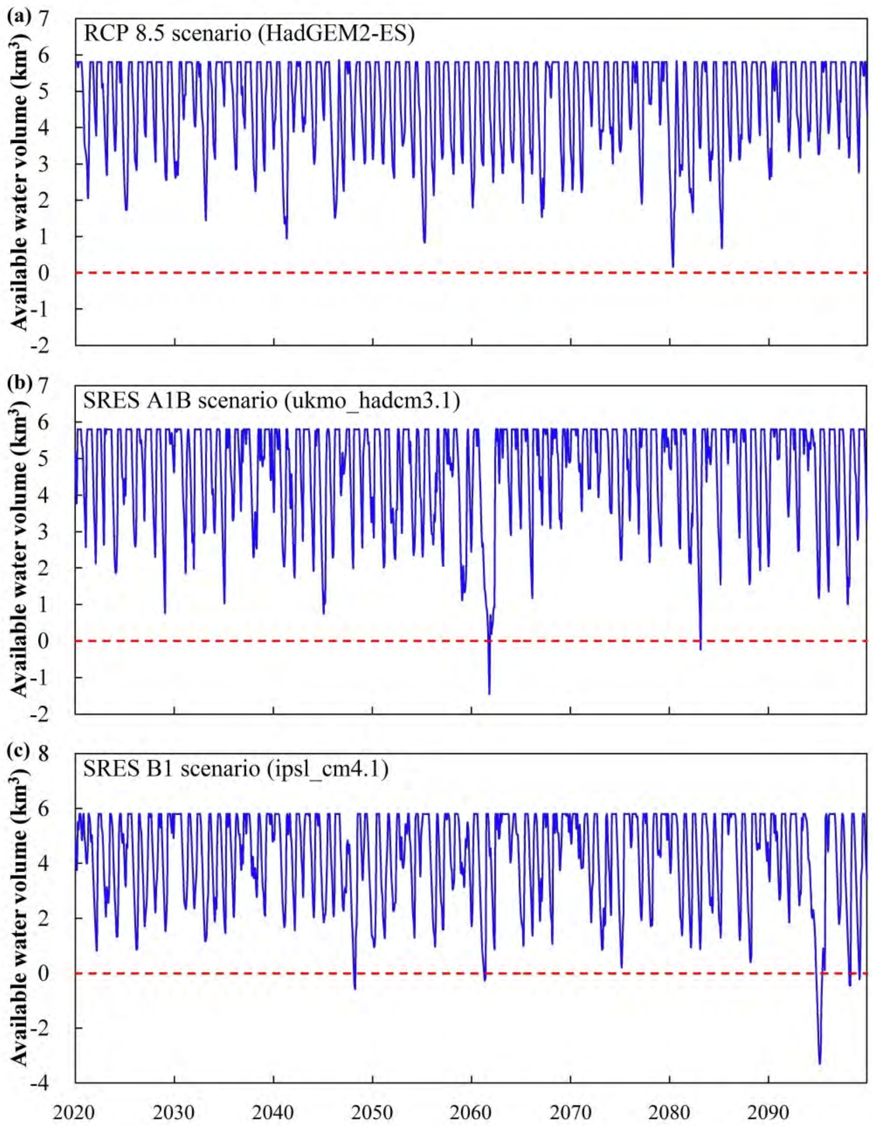
- **Impact of the XFJ Reservoir**
  - **The usable capacity of the XFJ Reservoir was 5.8 km^3 (Wu and Chen 2012), which implied that at least nearly 90% of the effective storage (i.e., 6.5 km^3) of the XFJ Reservoir would be used to store water in the flood season**
  - **For the selected 1 AR5 GCM, the usable capacity (5.8 km^3) of the XFJ Reservoir is sufficient to cover the largest cumulative water deficit (the largest RSP = 0.86 < 90%)**
  - **For the 16 AR5 GCMs, with the reservoir, even the smallest RSP value (i.e., 0.91) in Table 4 is larger than 90%, which means that water deficits will still remain in certain periods even if the adopted usable capacity is run out**

Results and discussion

- **Impact of the XFJ Reservoir**

The monthly available water volume in the XFJ Reservoir during 2020-2099 under three representative scenarios
-RCP 8.5 scenario with the largest RSP value of 0.86 (HadGEM2-ES)
-SRES A1B scenario with the largest RSP value of 1.11 (ukmo_hadcm3.1)
-SRES B1 scenario with the largest RSP value of 1.40 (ipsl_cm4.1)

The red dash lines denote that the usable capacity of the XFJ Reservoir (i.e., 5.8 km^3) is run out



Results and discussion

- **Impact of the XFJ Reservoir**

The relationship between the number of socioeconomic drought events and the used percentage of the effective storage of the XFJ Reservoir

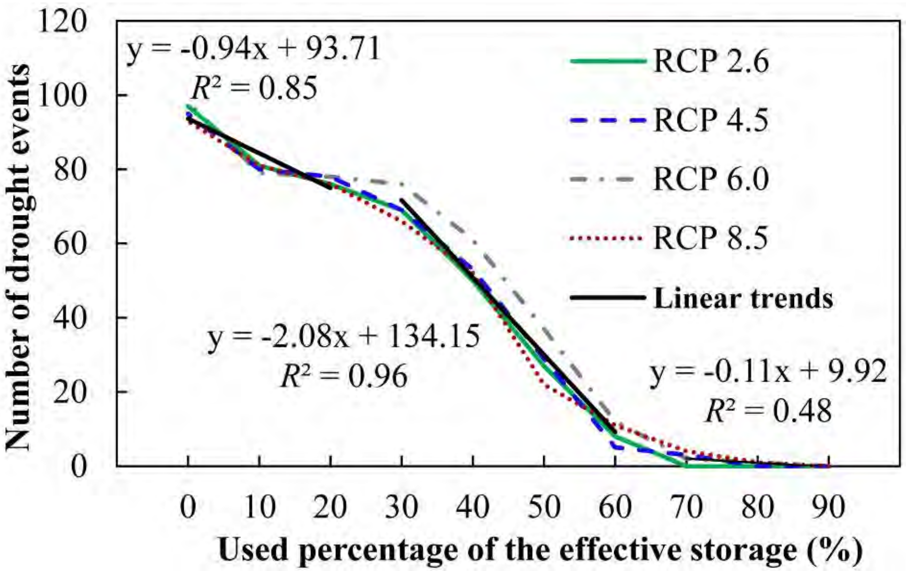


Table 6
The numbers of socioeconomic drought events when different percent of the effective storage of the XFJ Reservoir is used under each of the 4 scenarios of the 1 AR5 GCM.

Used percent	Total	SEDI = 1	SEDI = 2	SEDI = 3	SEDI = 4	Total	SEDI = 1	SEDI = 2	SEDI = 3	SEDI = 4
	RCP 2.6 scenario					RCP 4.5 scenario				
0	97	19	24	53	1	95	16	25	54	0
10%	81	8	37	36	0	80	3	44	33	0
20%	76	16	48	12	0	78	18	51	9	0
30%	69	30	27	2	0	69	36	30	3	0
40%	50	34	16	0	0	53	35	17	1	0
50%	27	24	3	0	0	29	24	5	0	0
60%	8	8	0	0	0	5	4	1	0	0
70%	0	0	0	0	0	3	3	0	0	0
80%	0	0	0	0	0	0	0	0	0	0
90%	0	0	0	0	0	0	0	0	0	0
	RCP 6.0 scenario					RCP 8.5 scenario				
0	98	21	20	55	2	93	16	27	49	1
10%	79	4	39	35	1	81	9	44	28	0
20%	78	14	53	11	0	76	18	44	14	0
30%	76	33	40	3	0	66	33	27	6	0
40%	61	37	22	0	0	52	37	14	1	0
50%	37	33	4	0	0	22	15	7	0	0
60%	12	12	0	0	0	11	8	3	0	0
70%	2	2	0	0	0	4	4	0	0	0
80%	1	1	0	0	0	1	1	0	0	0
90%	0	0	0	0	0	0	0	0	0	0

Conclusions

This study developed a new method (i.e., a heuristic method) and a new index (i.e., the SEDI) for identifying socioeconomic drought events on different severity levels under climate change through comprehensively evaluating the impacts of both water shortage and drought duration.

1. **The MWR value of the East River basin during 2010-2099 was obtained through considering the change of water demand in the future**
2. **The socio-economic drought events in the future were identified under different climate change scenarios**
3. **The result indicated that a number of droughts more severe than the 1963 drought might occur in this century**
4. **Through analyzing the impact of the XFJ Reservoir on future drought, this study indicated that most of the identified severe droughts could be mitigated by reservoir operation**

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Thank You !

International Workshop on Water Resources Management
May 29-30, 2018, The University of Hong Kong

Urban Flooding:
From Flood Control to Integrated Management

Prof. Zongxue Xu

College of Water Sciences, Beijing Normal University

Beijing Key Laboratory of Urban Hydrological Cycle & Sponge City Technology

Outline

- Background
- Flood Simulation
- Sponge City
- Conclusions

Background

Introduction

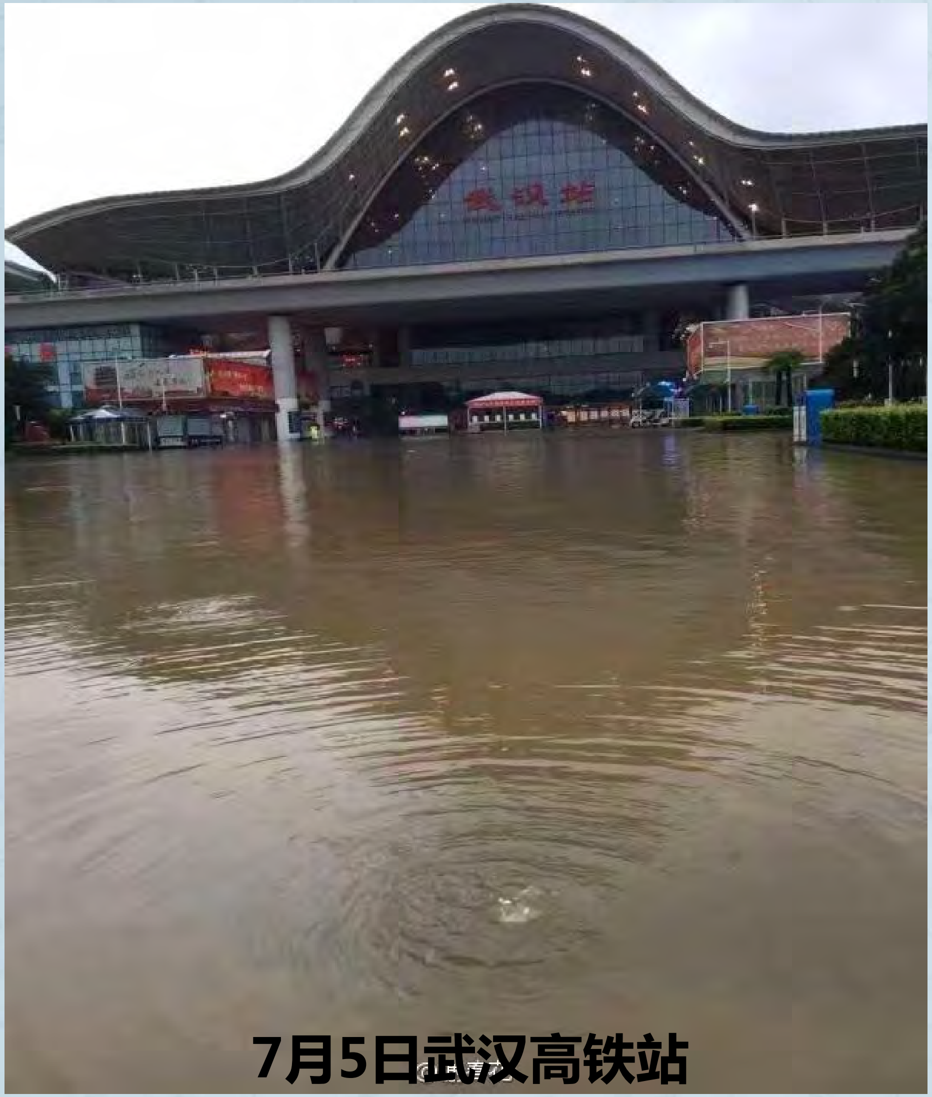
善为国者必先除五害。水一害也，旱一害也，风雾雹霜一害也，疠（瘟疫）一害也，火一害也，此谓五害。五害之属水为大。

——管子•度地篇

A man who is adept at running a state should eliminate Five Hazards firstly. One is Flood; one is Drought; one is Harmful Weather including storm, fog, hail and frost; one is Pestilence, and one is Fire. These are called Five Hazards. Flood is the severest one among the Five Hazards.

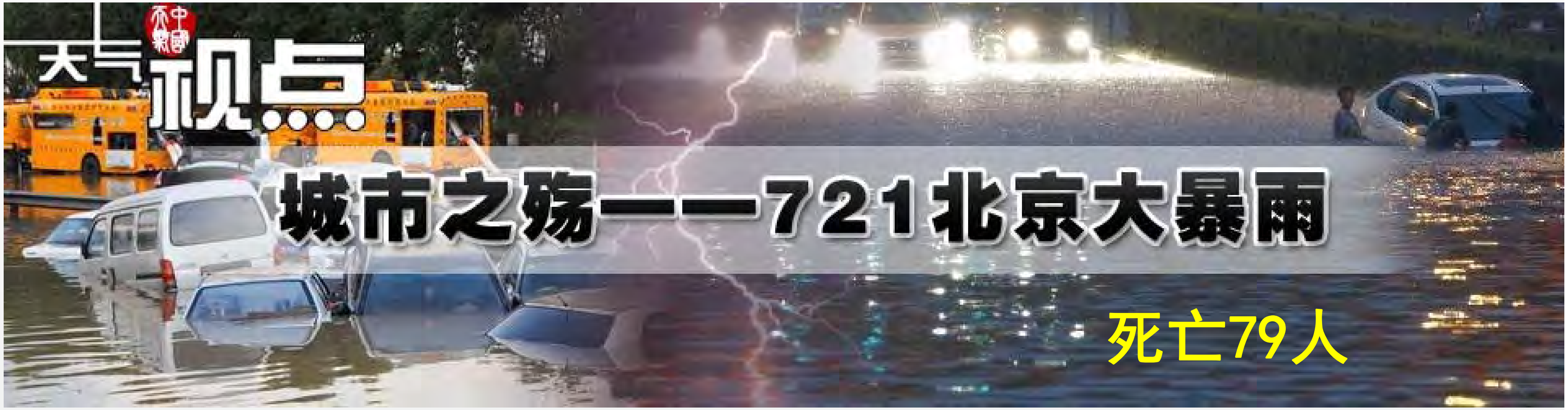
Guanzi, Land Administration

Urban Flooding in Wuhan in 2016



Urban Flooding in Beijing in 2012

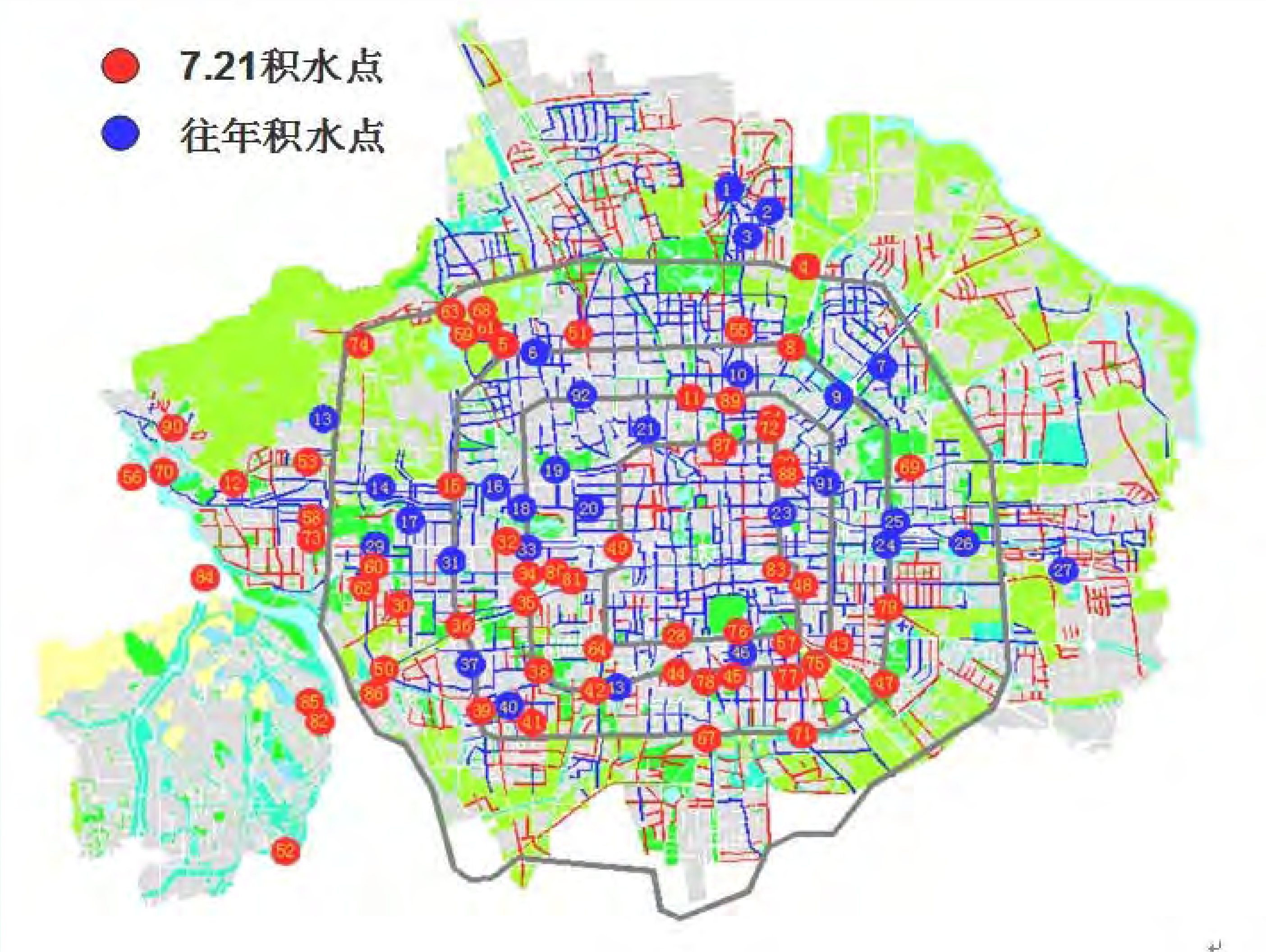
July 21, 2012



A car in floods in Beijing,
July 21, 2012

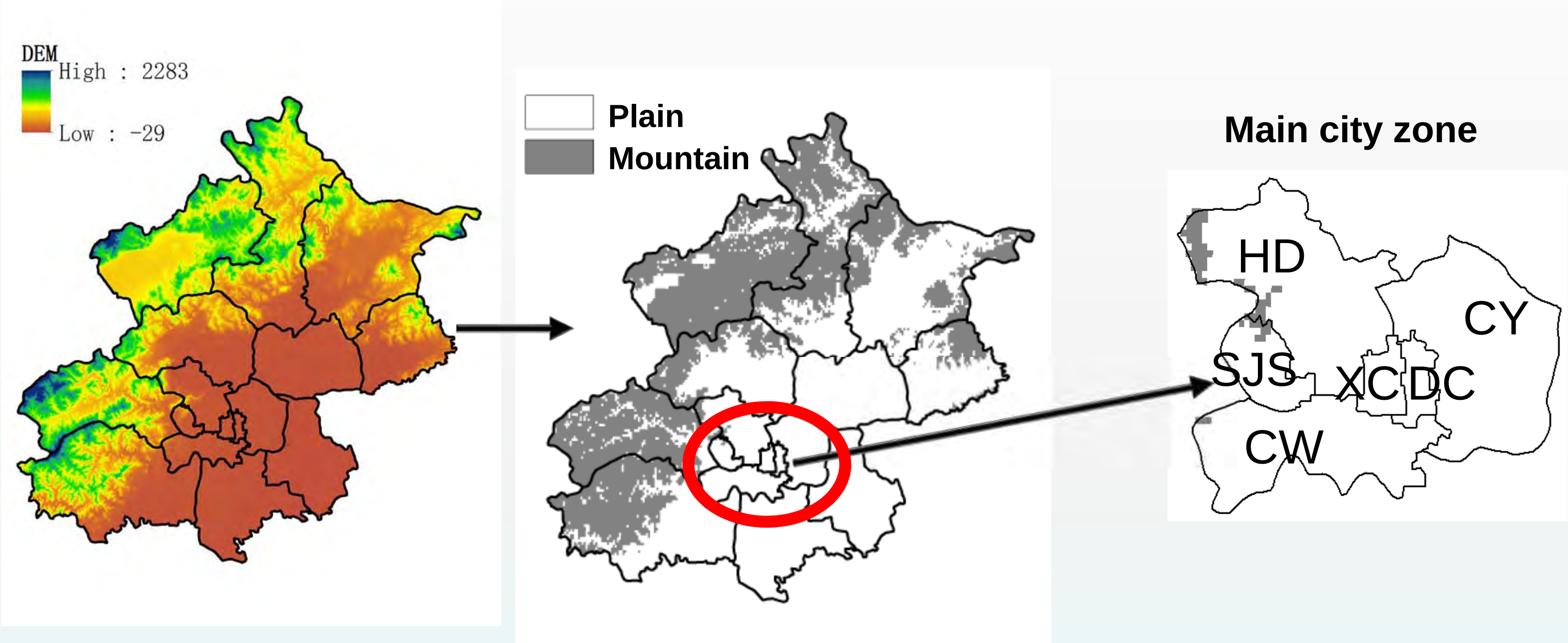
Xiangshan Garden
July 21, 2012

Flood Simulation: Case Study in Beijing



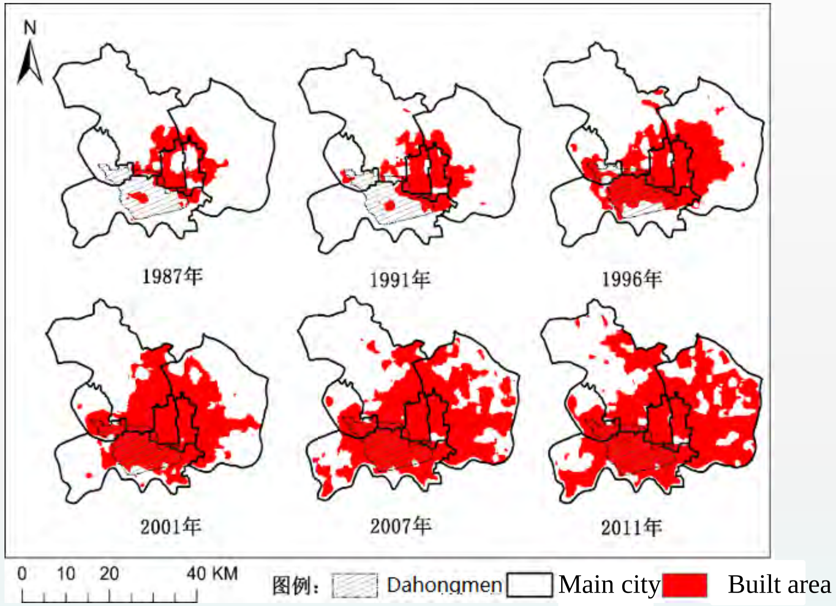
Inundation sites of “20120721” Rainstorm in Beijing

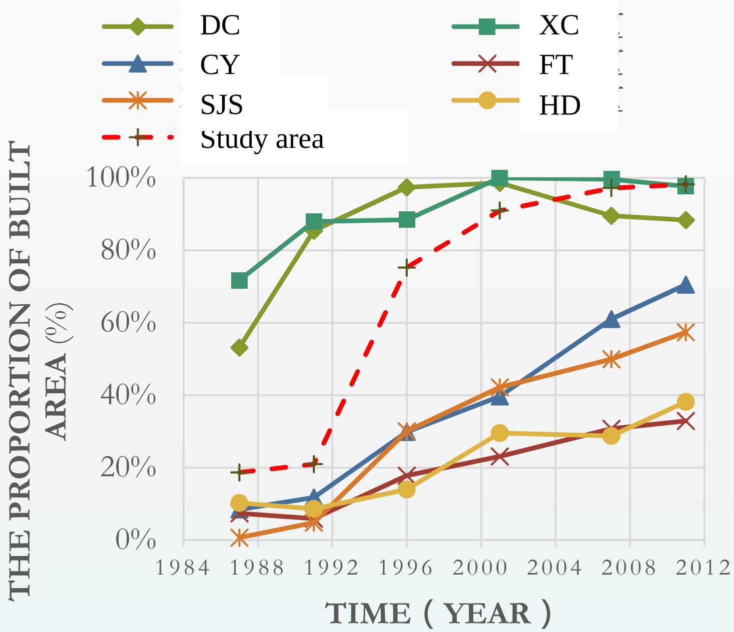
Study area



- Located in the northwest of the North China Plain, Haihe River Basin
- Two types of flooding: mountainous flood and plain flood
- Downtown of Beijing is influenced by plain floods.

Urbanization Processes





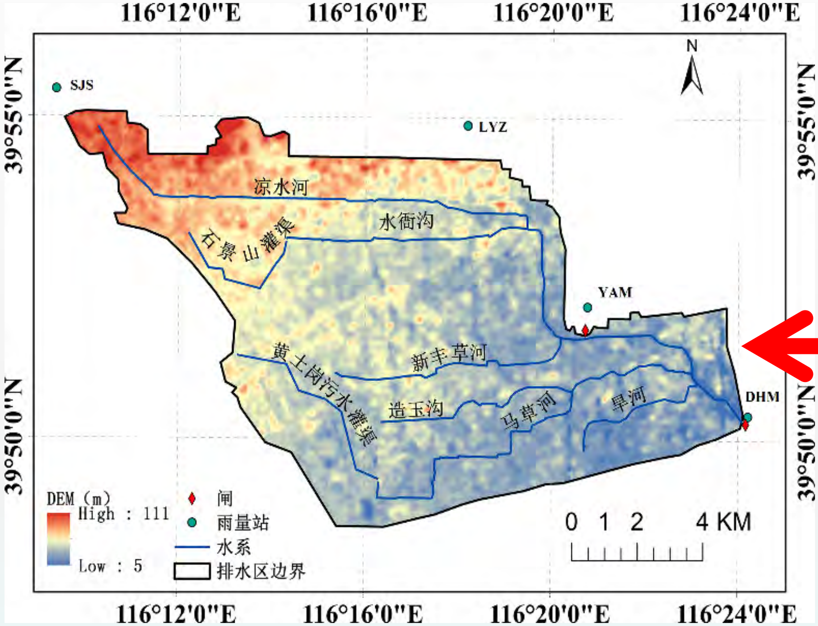
1992 : The flood diversion sluice was set up in YAM；

2004 - 2006 : Main channel was paved with concrete；

2006 : Open channel was replaced with closed conduit in Beijing West Railway Station;

…

Study Area



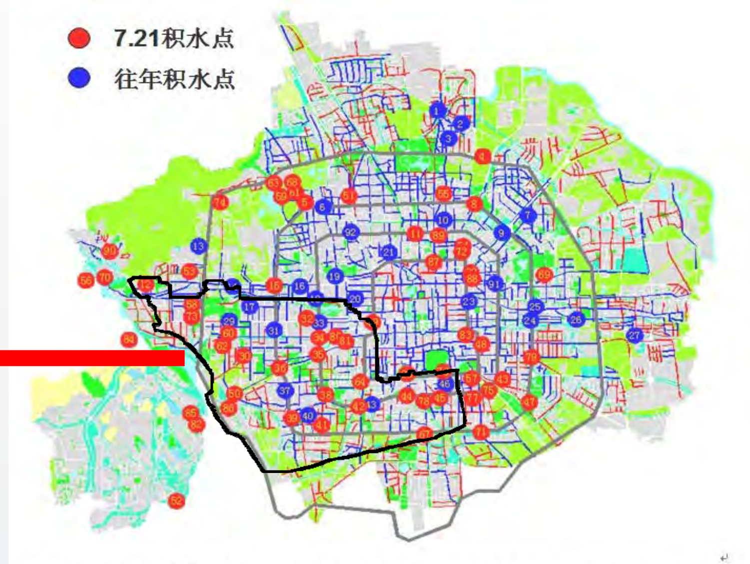


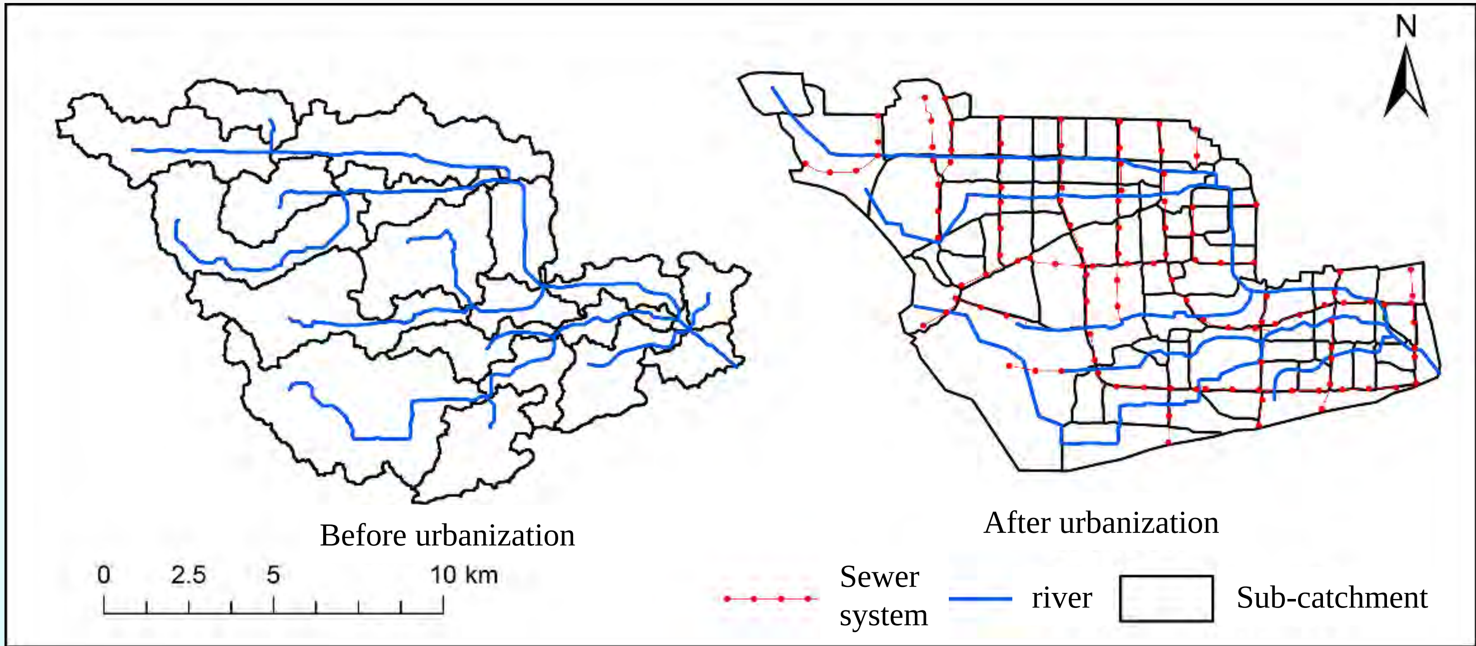
图 5 北京市中心城 2012 年“7.21”及历年严重积水点汇总

Dahongmen area is located in Liangshui River Basin, with a 131.48 km^2 drainage area and 522.4 mm average annual precipitation, which is one of the flood disaster prone areas in Beijing.

Almost 1/3 inundation sites in Beijing occurred in this area during the storm events of July 21, 2012

Model Development

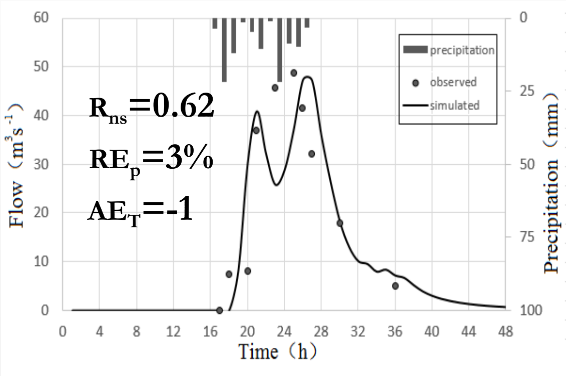
The intensive human activities should be considered in the simulation of rapid urbanized basin, such as the increasing impervious area, the river network structure, and drainage system.



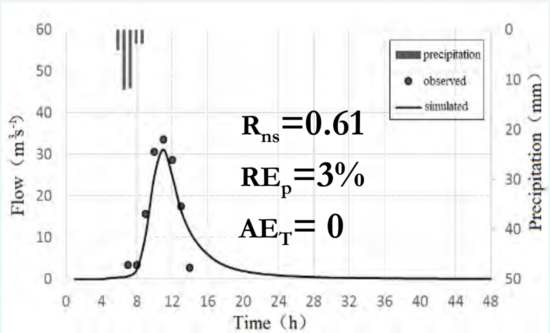
Model development in different urbanization cases

Before Urbanization

Calibration

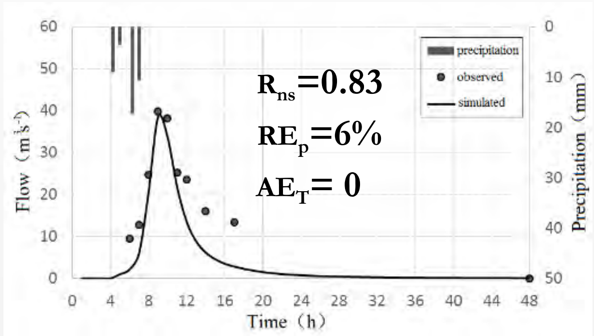


Storm “19810703”

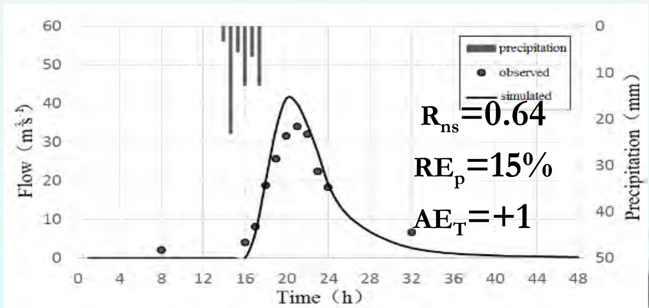


Storm “19830619”

Validation



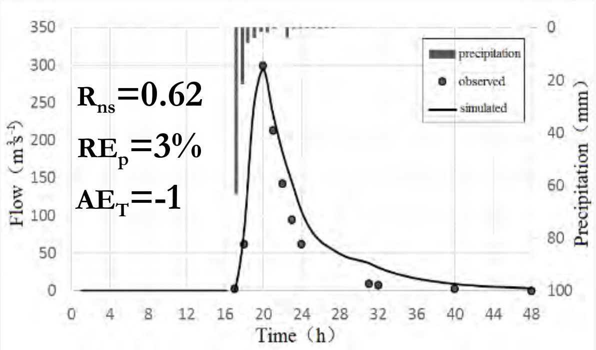
Storm “ 19850702”



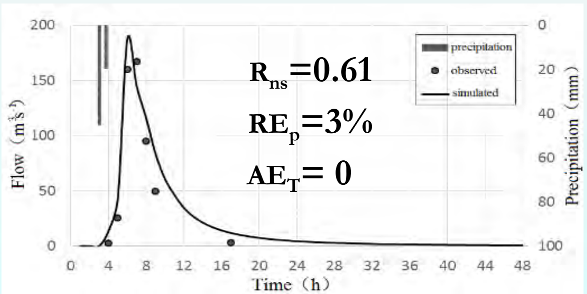
Storm “19870813”

After Urbanization

Calibration

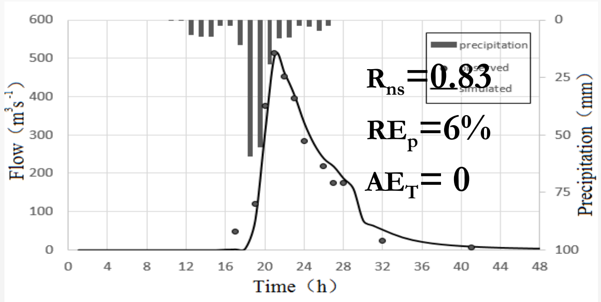


Storm "20110623"

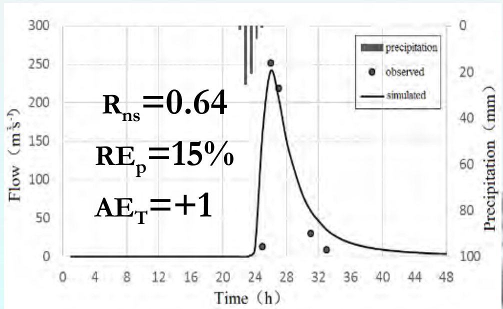


Storm "20120721"

Validation



Storm " 20110814"



Storm "20110726"

Impact of Urbanization on Floods

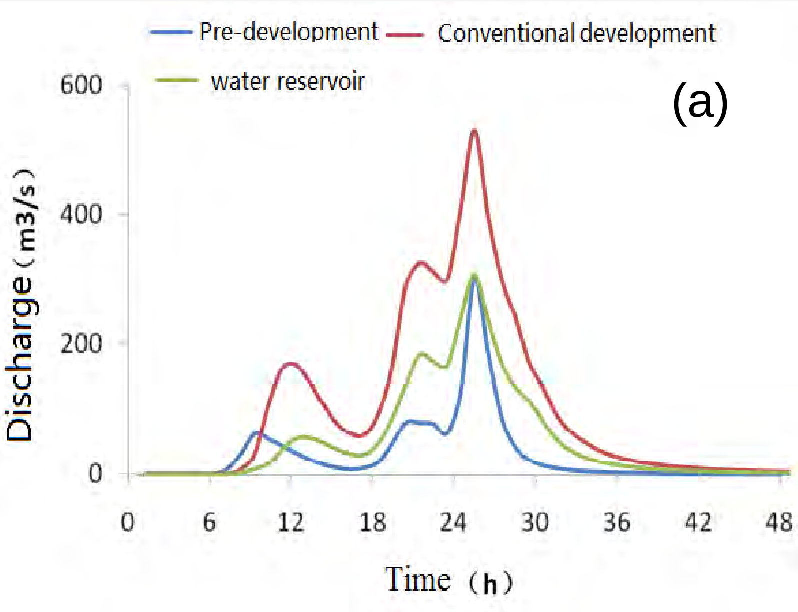
Hydrological Various	1-year return-period		5-year return-period		20-year return-period		50-year return-period		100-year return-period	
	before	after	before	after	before	after	befor e	after	befor e	after
precipitation	47.7	47.7	150.4	150.4	260.3	260.3	335.9	335.9	395.0	395.0
runoff	5.5	14.6	17.9	66.3	30.3	109.8	40.0	136.3	48.6	161.1
Runoff-Coefficient	0.12	0.31	0.12	0.44	0.12	0.42	0.12	0.41	0.12	0.41
Peak flow	30.6	64.3	118.7	337.4	208.5	438.6	298.8	526.7	384.9	612.8
Peak time	3h	5h	2h	3h	2h	2h	2h	2h	2h	2h

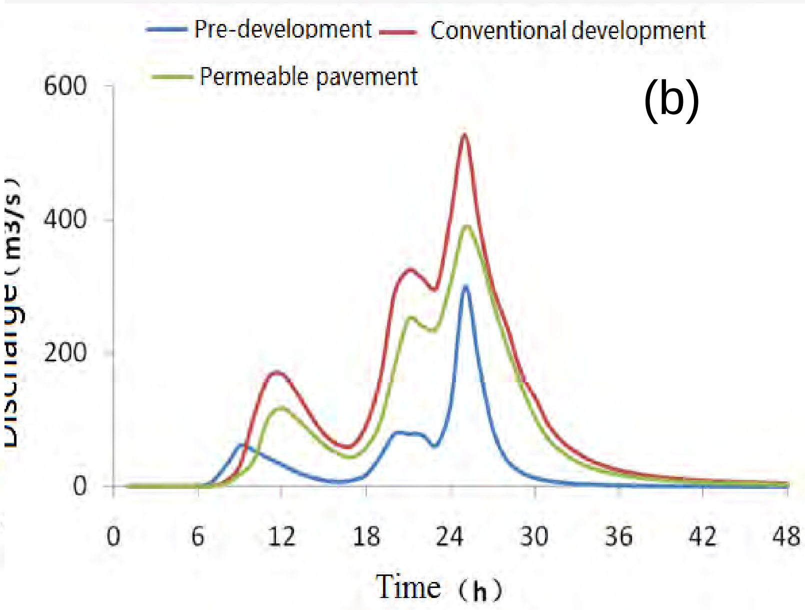
Summary

- Surface runoff after urbanization was 3.5 times greater than that before urbanization;
- The coefficient of runoff showed a significant increase from 0.12 to 0.41, and the amount of infiltration decreased from 88% to 60%;
- Peak flow of 20-year return-period after urbanization is greater than that of 100-year return-period before urbanization.

Low Impact Development

(a) Lianhua lake was acted as water reservoir for 50 year rainfall return period in Liangshui catchment.
(b) All land surface have been set to permeable for 50 year rainfall return period in Liangshui catchment.





50-year rainfall runoff hydrographs

Urban Storm Management

- **Drainage systems of urban main area in Beijing**

1. Qinghe River;

Area:175 km^2

Design drainage standard：20-50 year

2. Bahe River ;

Area:156 km^2

Design drainage standard：20-50 year

3. Tonghui River

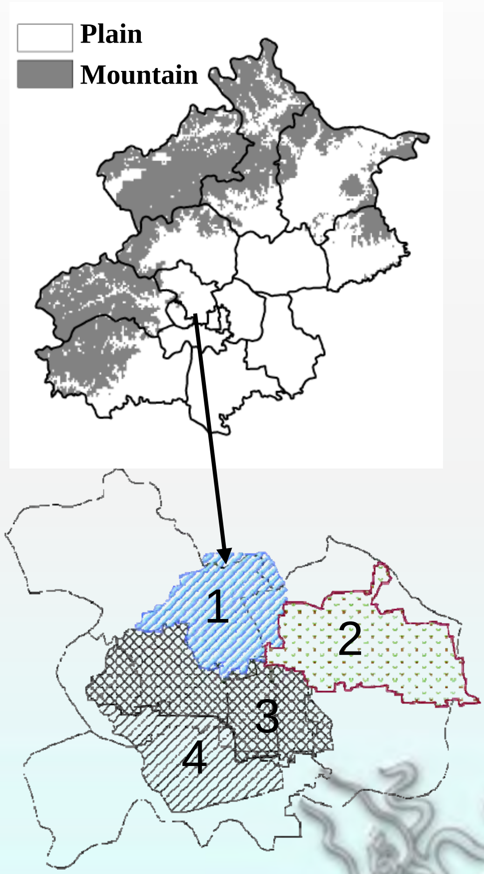
Area:258 km^2

Design drainage standard：20-100 year

4. Liangshui River

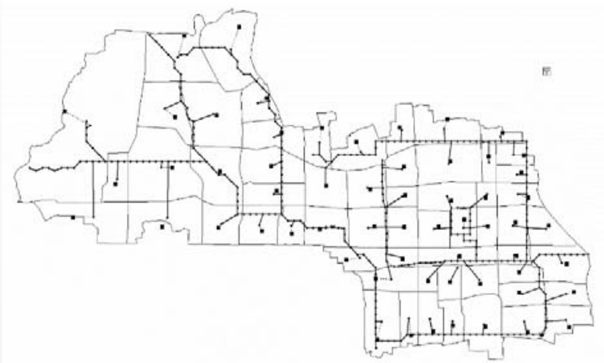
Area:131 km^2

Design drainage standard：20-50 year



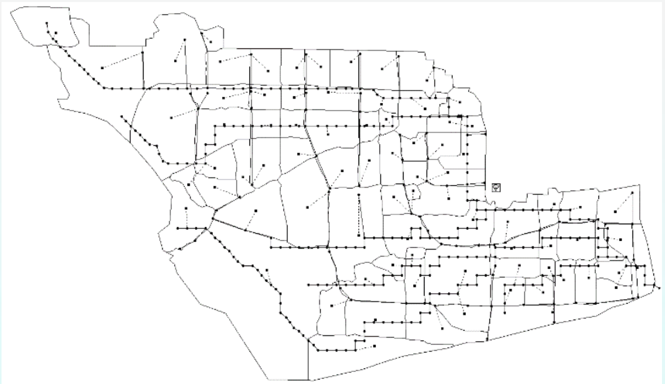
Drainage systems in Beijing

Urban Storm Management

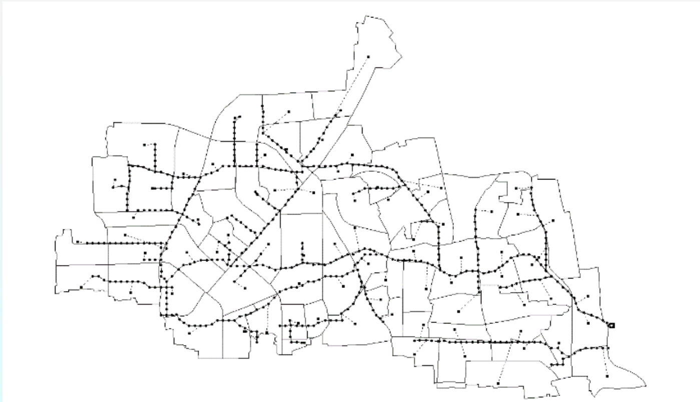


(1) Tonghui Catchment

(2) Qinhe Catchment



(3) Liangshui Catchment

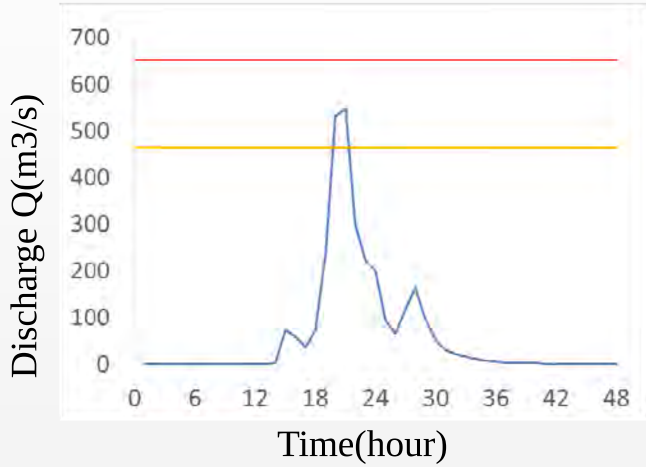


(4) Bahe Catchment

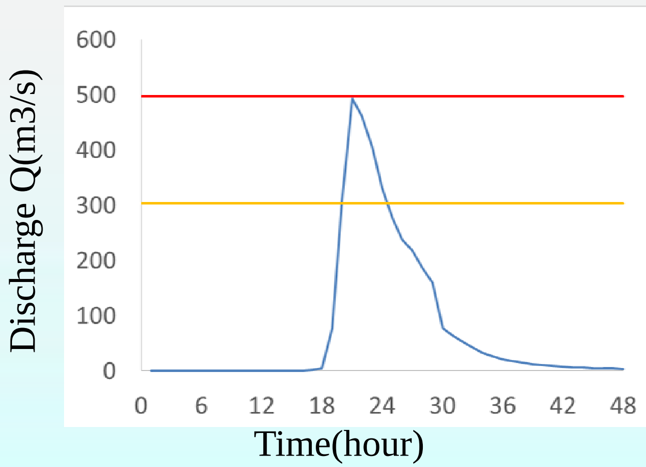
Drainage systems were developed by using SWMM

Urban Storm Management

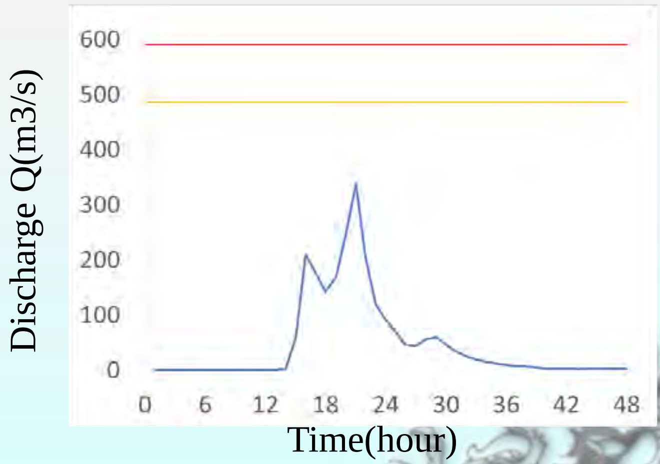
- **Comparison of simulated discharge in the storm events of July 21, 2012.**
- **About 30% quantity of water in Liangshui catchment come from Tonghui catchment in this event.**
- **Red : check flood discharge**
- **Yellow: design flood discharge**



(1) Tonghui Catchment

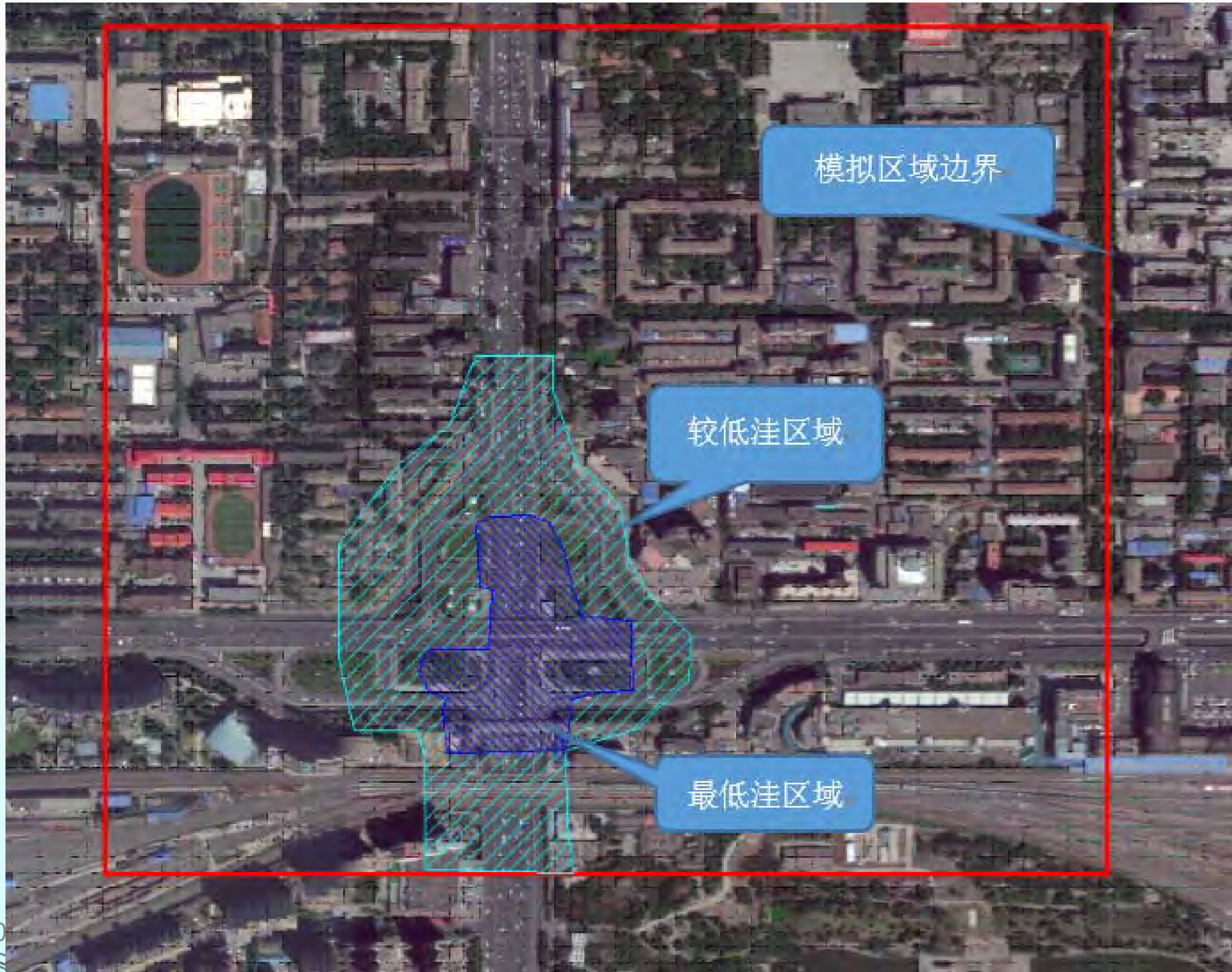


(2) Liangshui Catchment

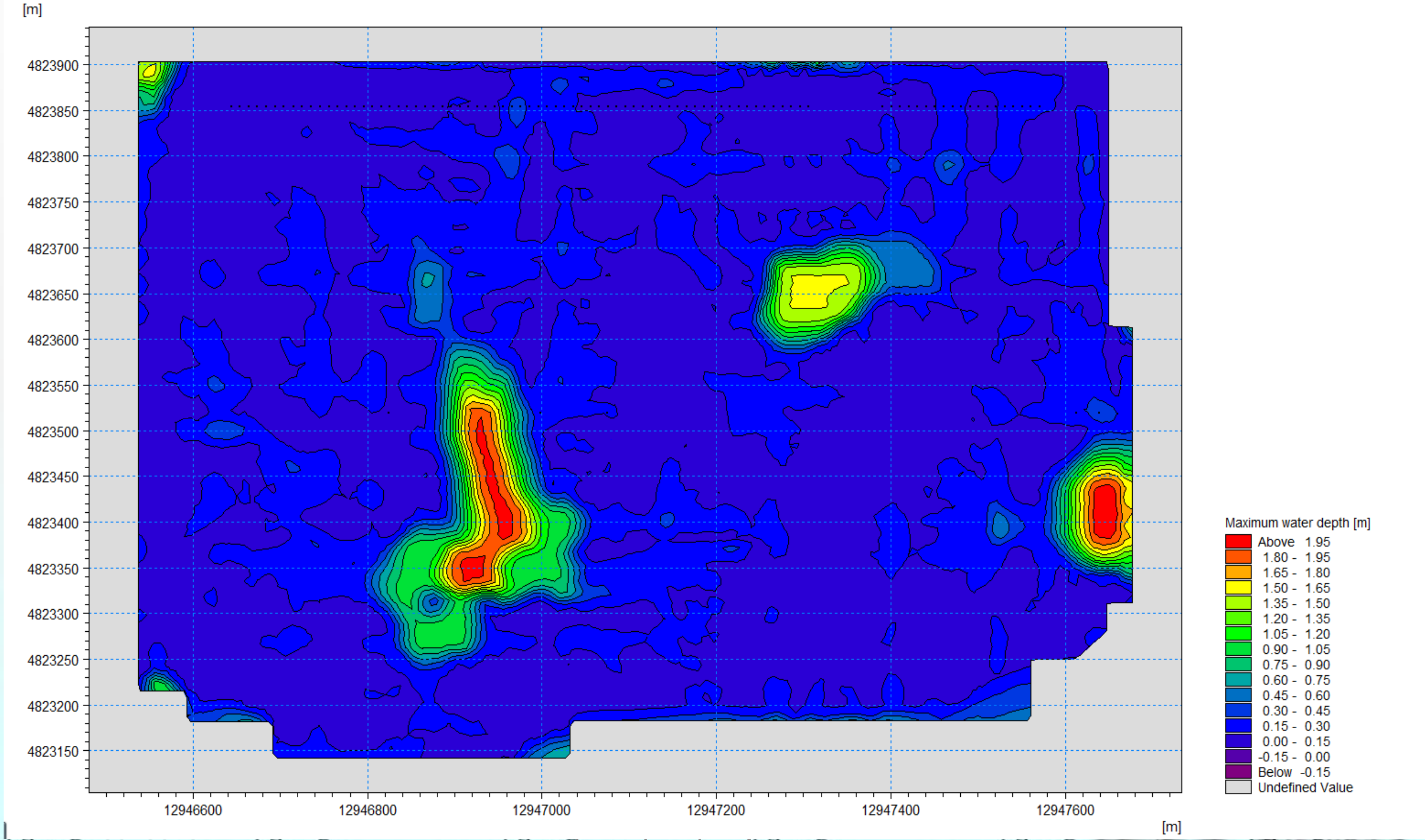


(3) Qinhe Catchment

Simulation at the Lianhua Bridge

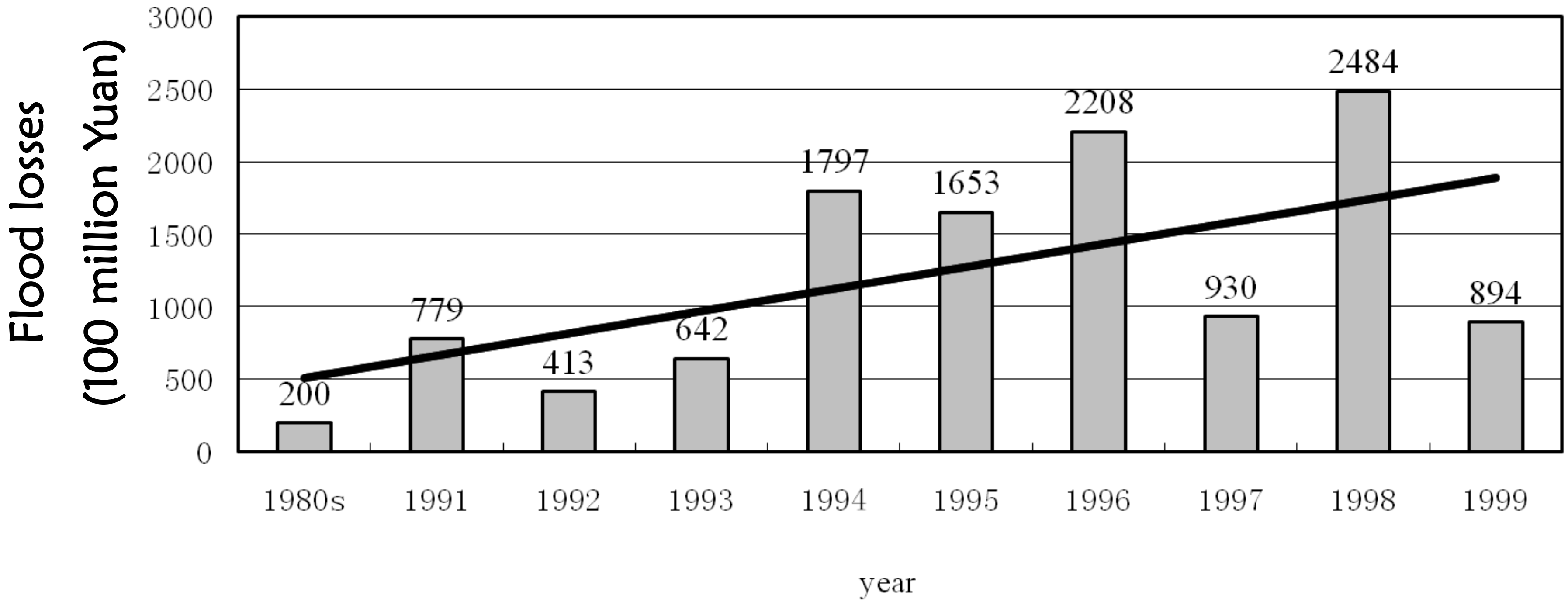


Simulation at the Lianhua Bridge



Sponge City Construction: Demonstration Projects

Flood Losses in China Since the 1980s



Sponge City Construction

Best Management Practices (BMPs) : United States, Canada

Low Impact Development (LID) : United States, England, Canada

Sustainable Drainage Systems (SUSD) : England, Sweden

Water Sensitive Urban Design (WSUD) : Australia

Low Impact Urban Design and Development (LIUDD) : New Zealand

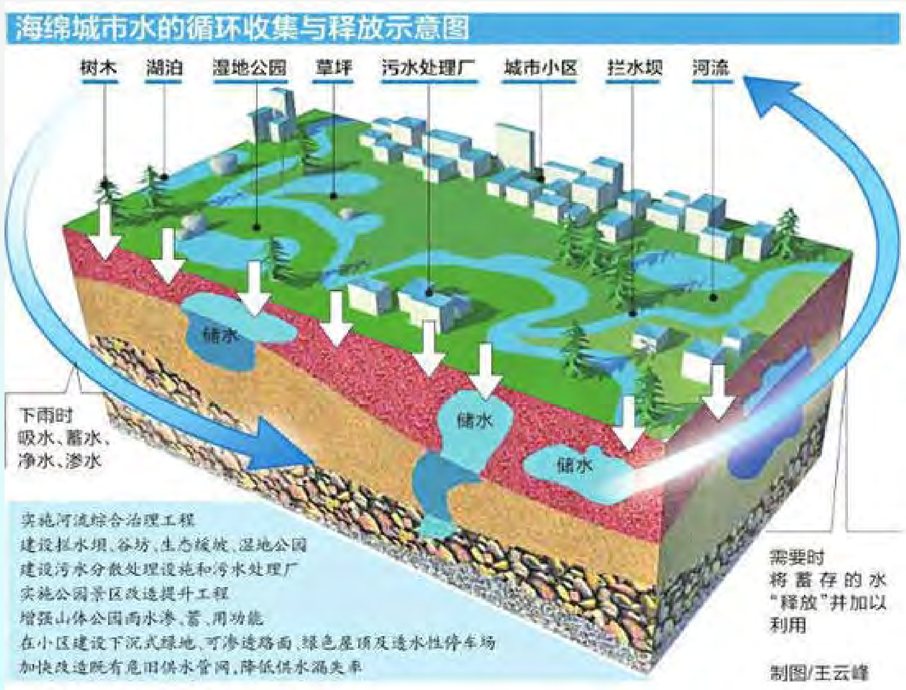
China: 《Technical Guide to The Construction of Sponge City》 by Ministry of Housing and Urban-rural Development of China, 2014.10

Pilot Cities for Sponge City Construction

2015: 16 Cities: Wuhan, Chongqing, Nanning, Xiamen, Jinan, Zhenjiang, Jiaxing, Changde, …

2016: 14 Cities: Beijing, …

Budget: 86.5 bi. yuan for 3 years , 0.19 bi. yuan /km2



Lessons for the Past

1. Rapid urbanization without rational planning
2. Limited involvement of water authorities in urbanization
3. Limited involvement of experts in the development of cities

Examples

Decreased urban storage capacity

1. **Nanjing: Water surface area decreased from 20% to 2%**
2. **Wuhan: Water surface area decreased from 25% to 4%**
3. **Beijing: Water surface area decreased from 5.74 km^2 to 4.96 km^2 (14% reduction)**

New Conception on Water Hazard Mitigation Policy

- Change from “Flood control” to “Integrated management”
- Change from “Drought fight” to “Comprehensive drought management”

Harmonious Relationship With Nature

Flood	**Give Space for Flood**
Drought	**Water-saving Society**
Pollution	**Green Development**

conclusions

Conclusions

- **Impact of urbanization on flooding is significant, resulting in an increase of the flooding risk;**
- **The peak flow of 20-year return-period after urbanization is greater than that of 100-year return-period before urbanization;**

Conclusions

- **High flood risks are often resulted from heavy rain within short duration, and can be avoided or reduced by sponge city project and timely flood relief measures;**
- **Low Impact Development and flood diversion can effectively mitigate the flood risk on peak and volume of flood;**

Conclusions

- Integrated management and governance are more important than techniques itself;
- How to transfer the good techniques to governance will be a great challenge.

Objectives in 2050

Water Resources – Sustainable uses

Water Environment – Healthy Environment

Water Ecology – Safe Ecology

Water Disaster – Protection and mitigation

Water Management – Harmonious Development

Thank You for Your Attention！

Prof. Zongxue Xu

College of Water Sciences

Beijing Normal University

E-mail: zongxuexu@vip.sina.com

Website: http://www.zxxu.org/