Global Water Cycle Change and Risk of Extreme Hydrological Events

Yong Luo
(presented by Hui Lu)
Department of Earth System Science
Tsinghua University

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Outlines

01 Global Water Cycle Change in past and future

02 Extreme Hydrological Events in China and world

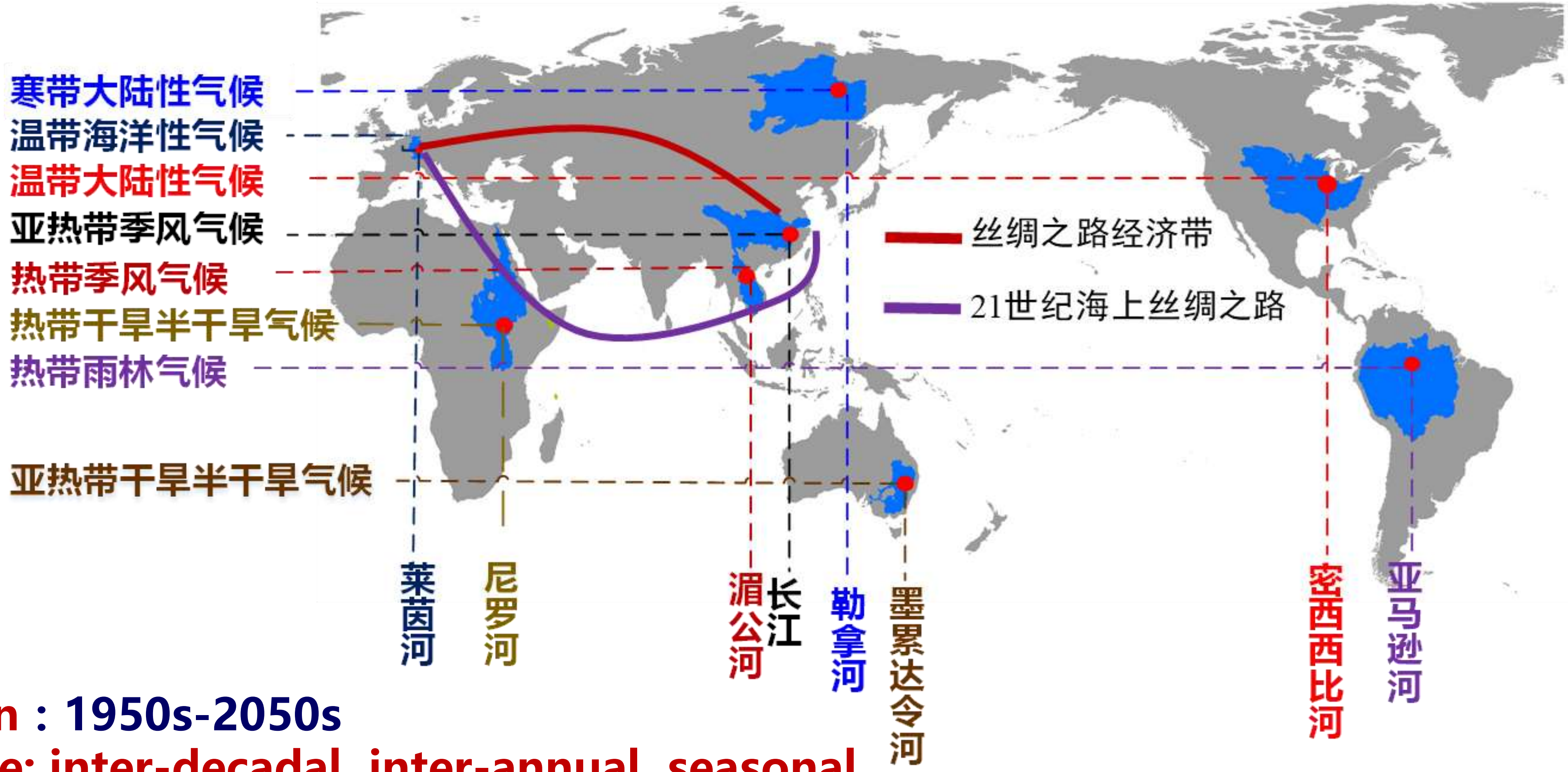
03 Mitigation and adaptation of risk

Background

Sci. Q.		Contents	
Changes in the Past	The energy and water cycles in the climate syst.	**1. The detection of the change of the global energy and water cycles** Data sets of global water and energy cycles ; Characteristics of the interdecadal changes ; Changes and Mechanisms of Extreme Hydrological Events in Typical Basins	The Facts
Mechanism	The interactions among climate, land, and hydrology syst.	**2. Mechanisms and modelling of global land surface-hydrological process interactions** GLM, a globally distributed land-surface hydrological modelling system; natural forcing and anthropogenic impacts	Scientific Understanding
		3. Global coupled sea-land-air-ice models and attribution of extreme hydrological events CIESM-GLM; Attribution and prediction of the global energy and water cycle and the changes of extreme hydrological events	
Changes in the Future	The risk of extreme hydrological events	**4. Global Risk Assessment of Extreme Hydrological Events and China's Adaptation Countermeasures** Risk Sources and Risk Transformation of Extreme Hydrological Events; Indicator System for Quantitative Assessment of Risks; Adaptive Countermeasures for Extreme Hydrological Events in China	Adaptation & mitigation

Background

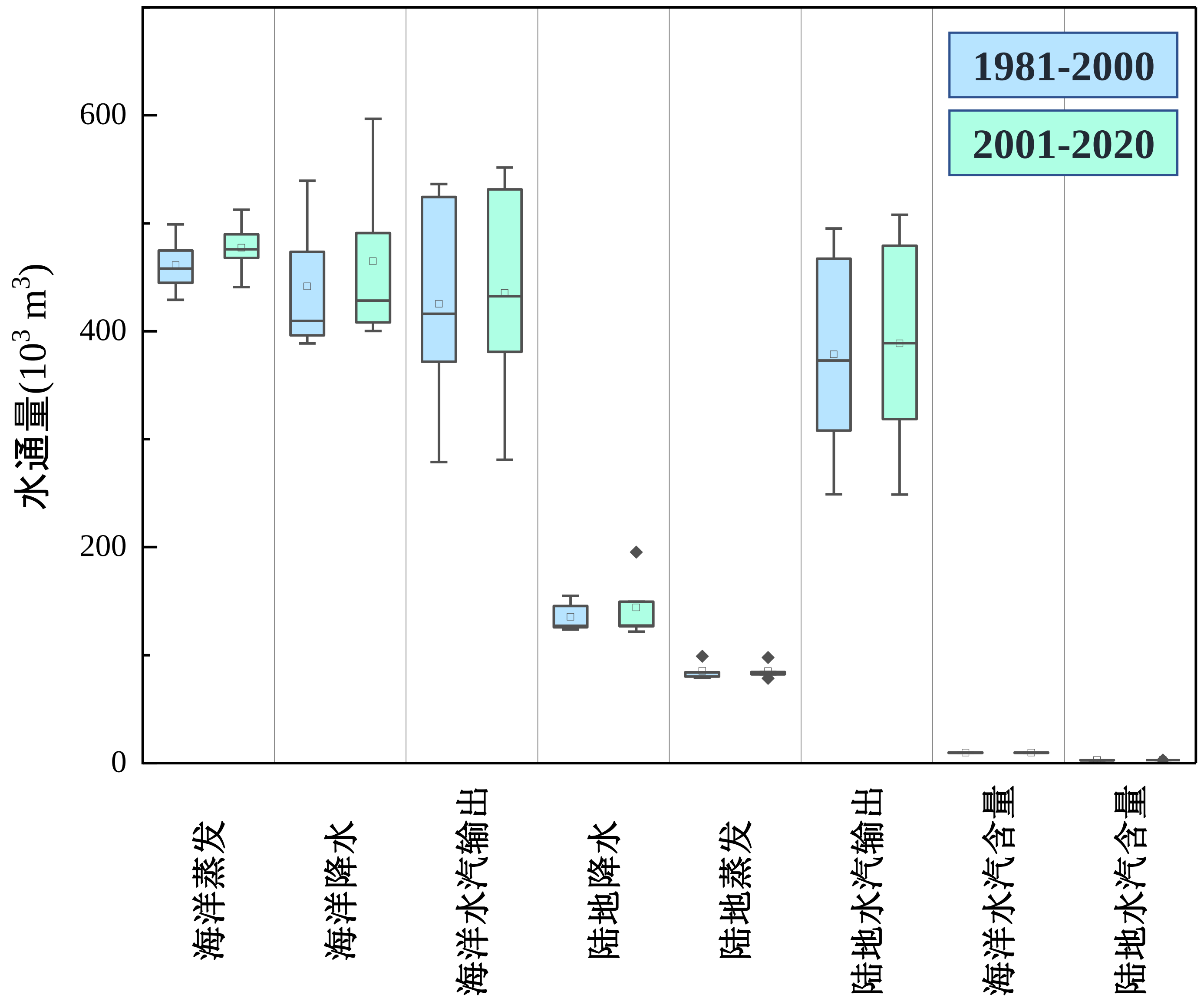
Supported by the National Key R&D Program "Global Change and Response". From the global as well as eight typical basins.



Time span：1950s-2050s
Time scale: inter-decadal, inter-annual, seasonal
Study Reg.: Global and eight typical watersheds (with a focus on the Belt and Road route)

1. Global water cycles

The fluxes of global water cycles



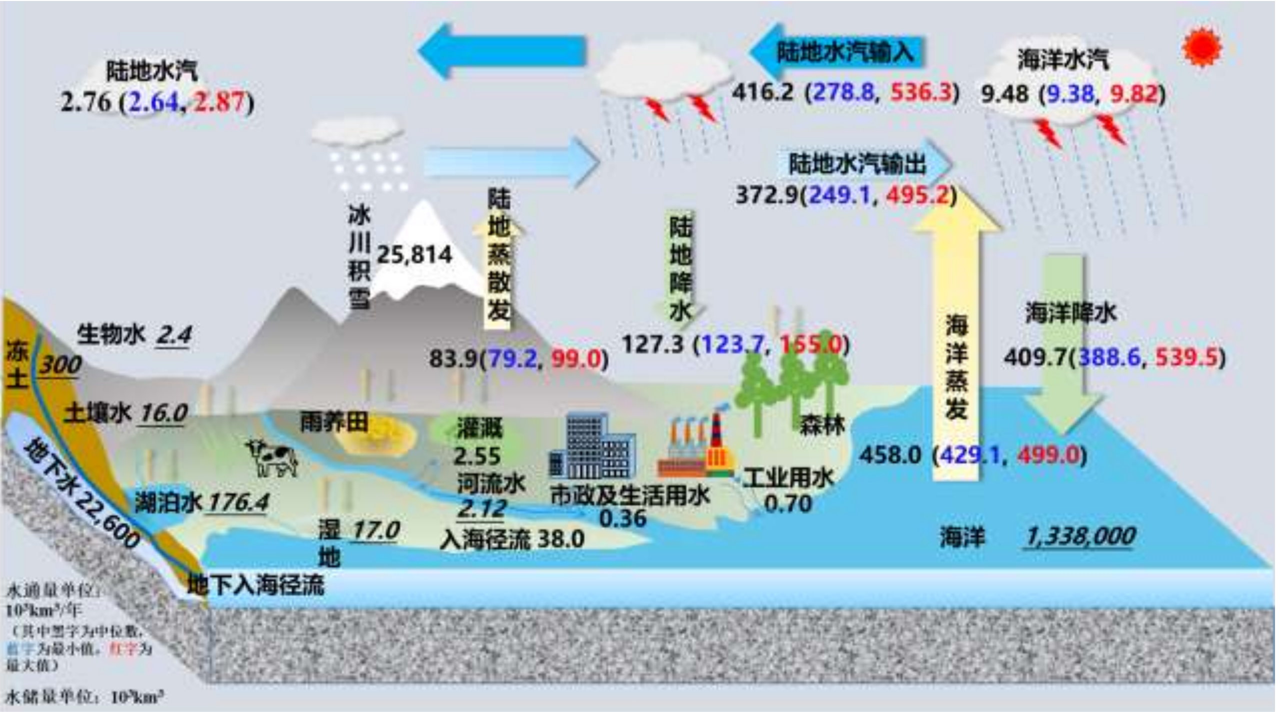
Intensified global water cycle

- Over the ocean, the evaporation, precipitation and water vapour transport all increased in varying degrees.
- Over the land, water vapour transport and precipitation increased, but evaporation decreased slightly.
- Ocean water vapour content and land water vapour content are relatively stable.

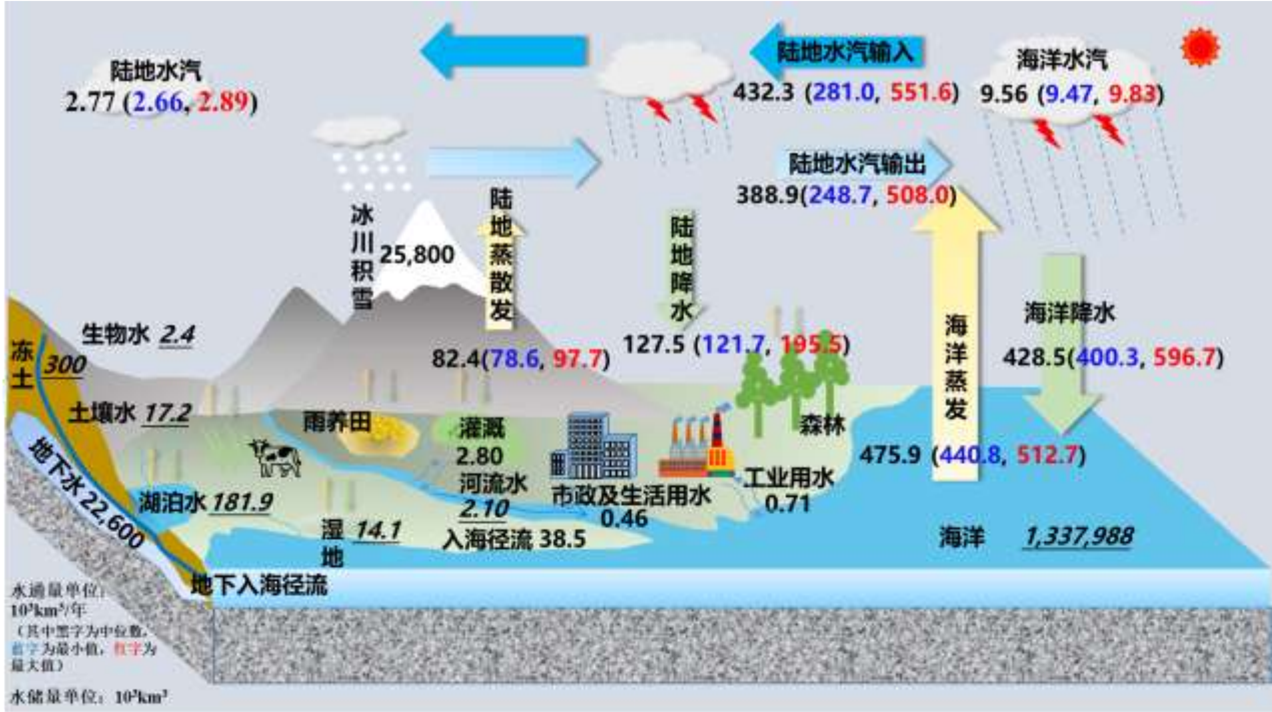
1. Past and future changes in the global water cycle

Dynamic images of the global water cycle

1981-2000



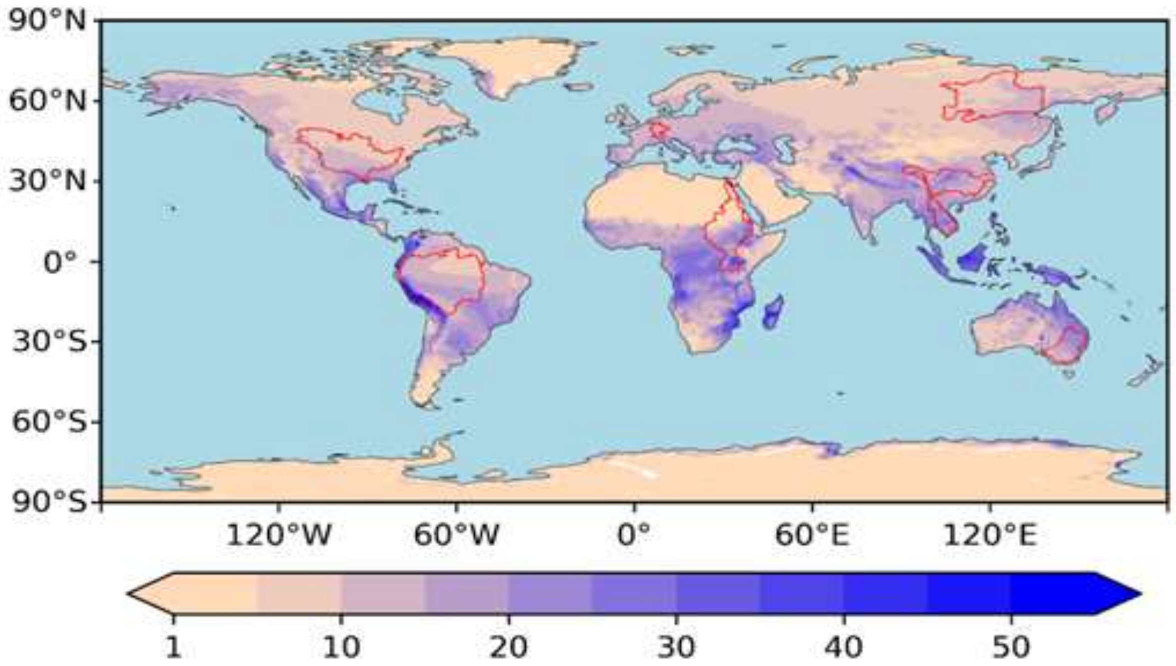
2001-2020



Compared to 1981-2000, under conditions of gradually intensifying socio-economic activities, there has been a global decrease in glacial snow cover, in wetlands and river water, in evapotranspiration from land, while an increase in land-sea water vapour interactions, in evaporation from the oceans, in precipitation on land, in the amount of water used for production and domestic purposes, and in soils, lakes and runoff to the sea.

1. Past and future changes in the global water cycle

Dynamic images of the global water cycle



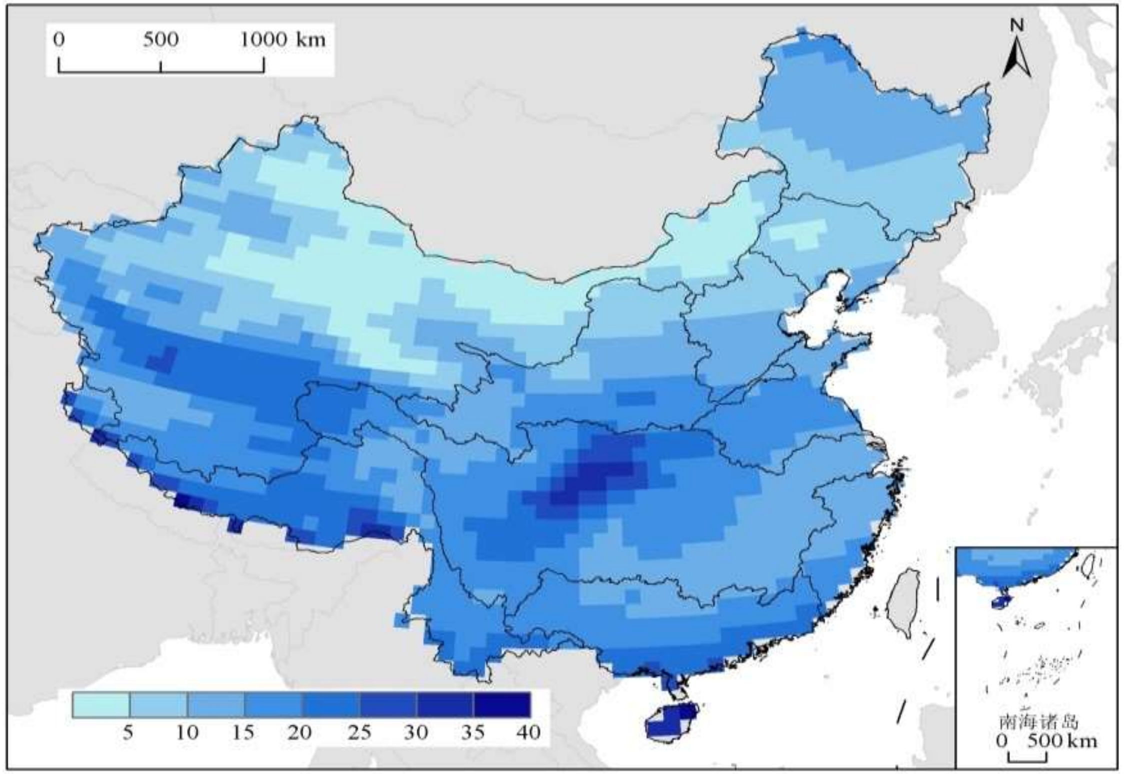
Spatial distribution of global terrestrial precipitation recycling rate (%)

	平均再循环率	水循环变化
亚马逊河	19.4	蒸发下降，纬向水汽输送增加，内循环减弱；
勒拿河	10.0	蒸发和水汽输送均增加，降水再循环率有所下降，表明水汽向外部输送增加。
湄公河	19.8	蒸发增加，水汽输送减弱，内循环加强。
密西西比河	12.0	蒸发增加，水汽输送增强，内循环减弱。
墨累达令河	17.6	内循环略有减弱
尼罗河	13.0	蒸发下降，水汽输送增强，内循环明显减弱。
莱茵河	12.3	蒸发增加，内循环显著加强。
长江	15.7	蒸发增加，水汽输送减弱，内循环加强。

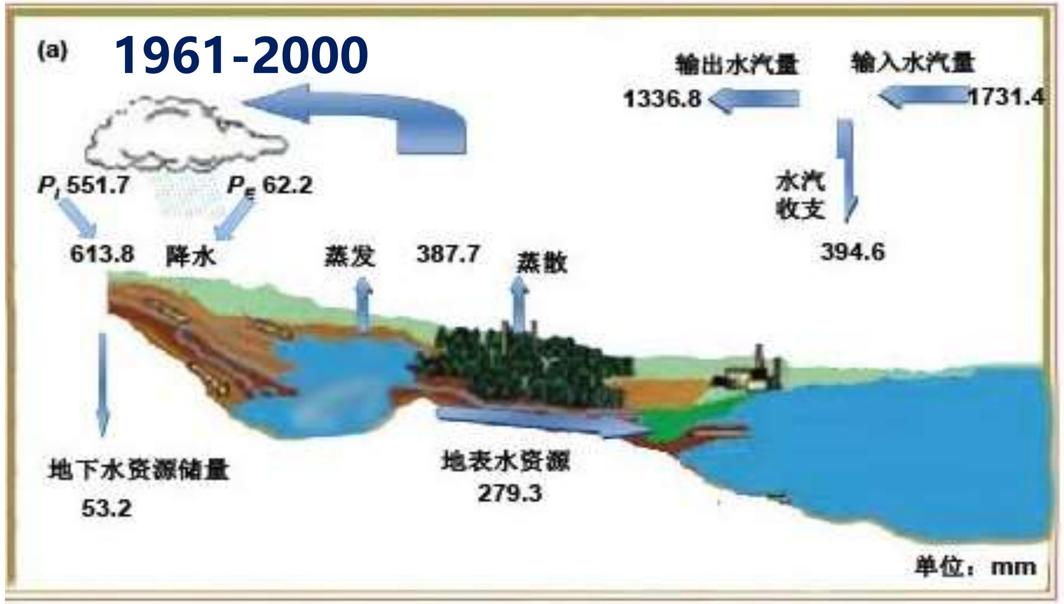
Changes in the water cycle in typical river basins, 1979-2020

1. Past changes in the global water cycle

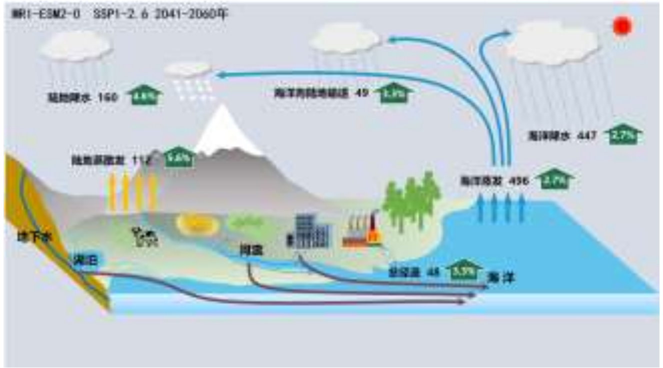
Dynamic images of the water cycle in China

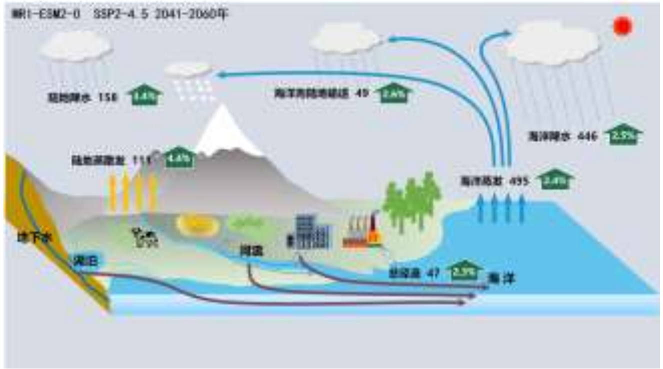


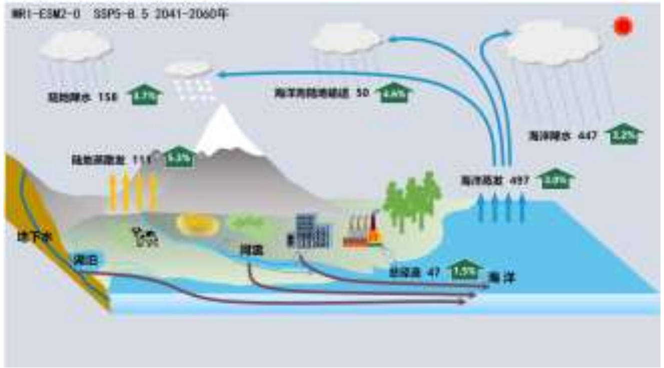
Precipitation recirculation rate in China, 1961-2019 (in per cent)

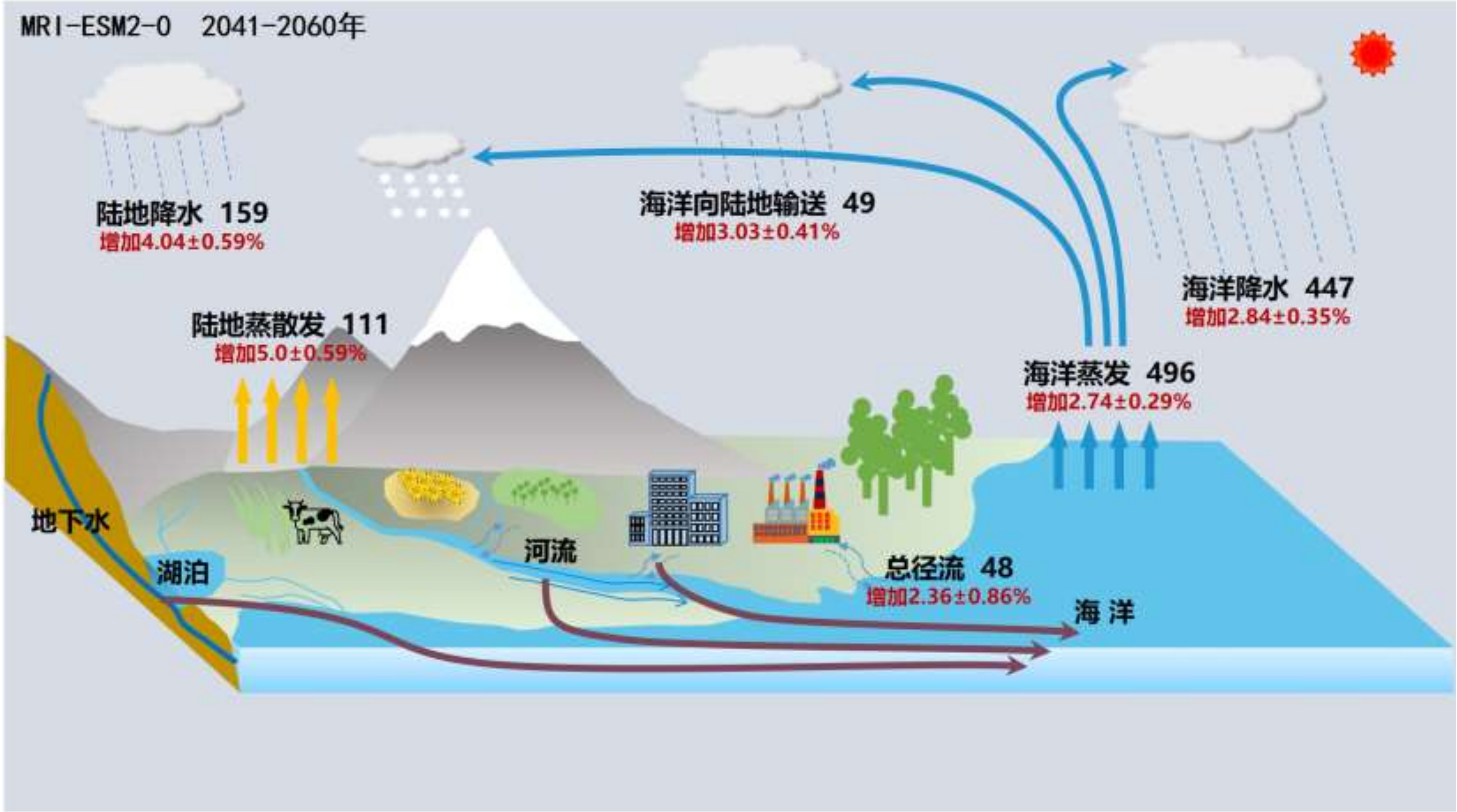


1. Future changes in the global water cycle









By mid-century, global ocean evaporation will increase by 2.74%, ocean precipitation by 2.84%, ocean-to-land water vapour transport by 3.03%, terrestrial precipitation by 4.04 , terrestrial evaporation by 5.00%, and total runoff depths by 2.36%: an acceleration of the global water cycle!

Outlines

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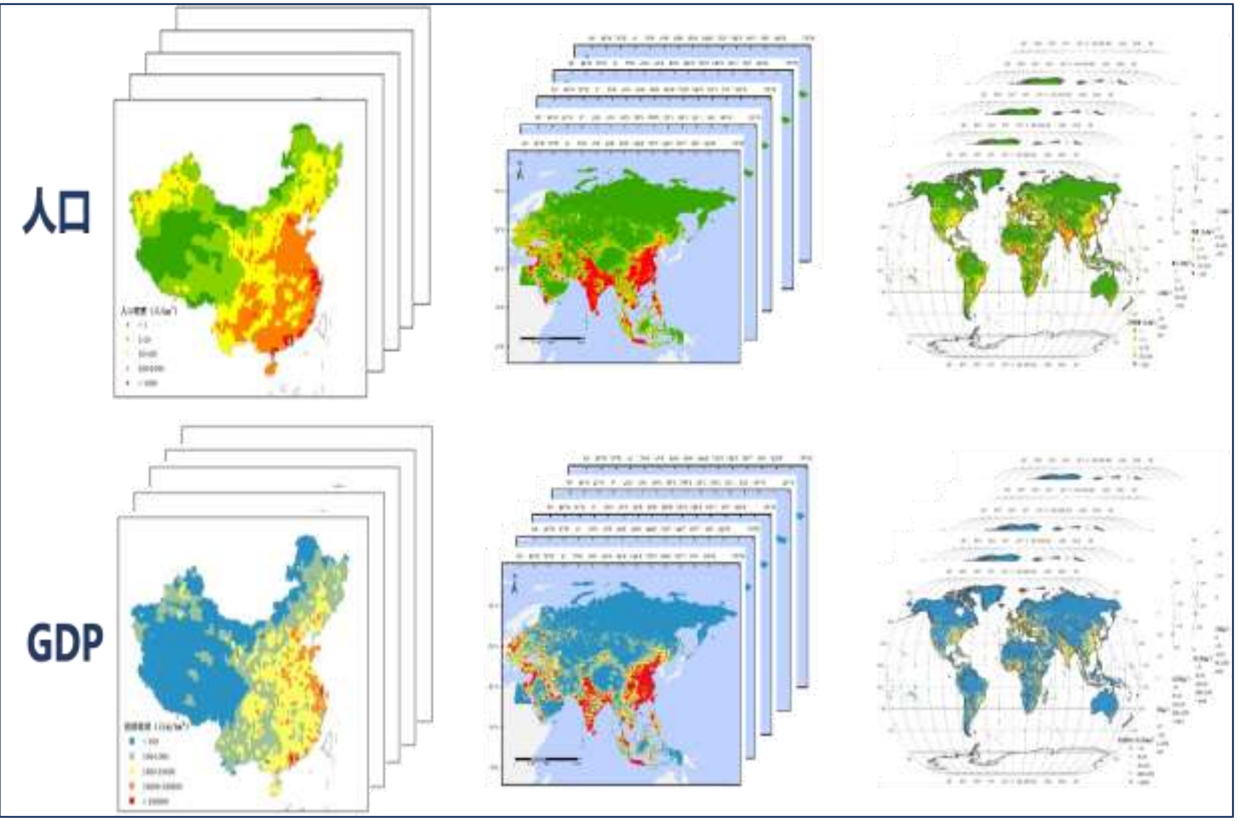
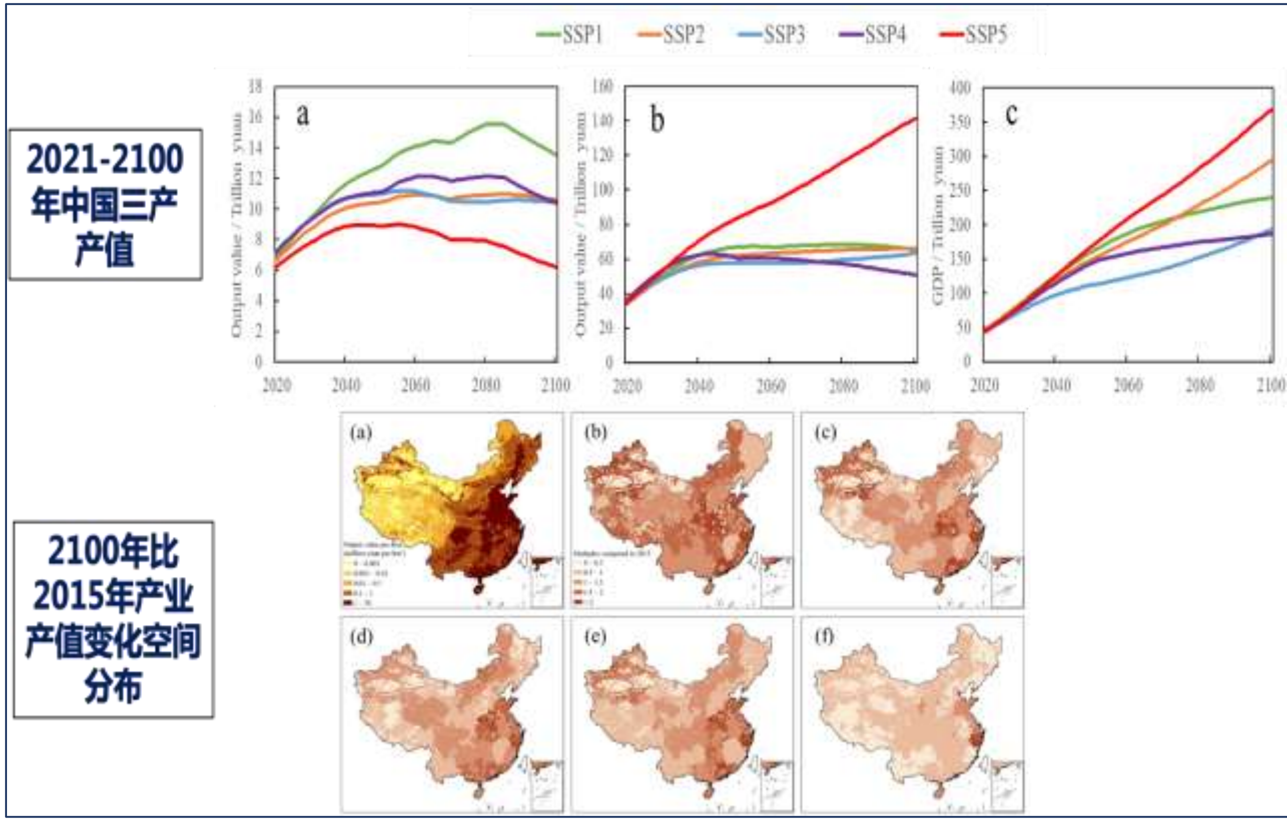
03 Mitigation and adaptation of risk

2. Risk of extreme hydrological events globally and in China

Research and development of future socio-economic scenarios





Gridded population and GDP for China, Belt and Road, and the world, 2020-2100 (0.5 degrees)

2. Risk of extreme hydrological events globally and in China

Multi-level and multi-pathway risk assessment of extreme hydrological events at the global-regional-basin scale

Theory of Risk Evaluation for Extreme Hydrological Events

发展了主观-客观-组合赋权综合权重动态计算方法，引入ROC曲线定量验证极端水文事件风险量化精度，定量验证所建立的极端水文事件风险量化计算方法具有较好的精度

□ 极端水文事件风险计算表达式

极端水文事件风险 =

极端水文事件/危险性 × 脆弱性 × 暴露度

$$HDRI = (VE^{we})(VH^{wh})(VS^{ws})$$

- HDRI为极端水文事件**综合风险指数**，其值越大，风险越大；
- VE、VH、VS分别为极端水文灾害**危险性、暴露性、脆弱性**各因子指数；
- we、wh、ws则为各评价**因子的权重**；

Indicator System for Extreme Flood Risk

目标层	因子层	子因子层	指标层
极端洪涝事件风险指数	危险性	洪水特征	最大洪峰
			洪量（3日、5日）
			最高水位
		暴雨特征	最大暴雨量（1日，连续3日，连续5日）
		自然地理特征	降水侵蚀力
			坡度
			高程
	暴露性	人口	人口密度指数
		经济	经济密度指数
		人类发展	人类发展度指数
	脆弱性	人口结构	0-15或>65岁人口比例
			性别比例
			教育水平
		经济脆弱	暴雨洪涝损失
		土地利用类型	易受淹农田、城镇比例
		行动	河网密度
			路网密度
		防洪能力	堤防长度
			堤防标准

Indicator system for extreme drought risk

目标层	因子层	子因子层	指标层
极端干旱事件风险指数	危险性	干旱特征	干旱面积
			干旱历时
			干旱频次和强度
		气象要素	连续干日（无雨日）
			日最高气温
		自然地理特征	坡度
			高程
	暴露性	人口	人口密度指数
		经济	经济密度指数
		人类发展	人类发展度指数
	脆弱性	人口结构	0-15或>65岁人口比例
			性别比例
			教育水平
		经济脆弱	干旱损失
		土地利用类型	易受旱农田、城镇比例
		行动	河网密度
			路网密度
		防灾抗旱能力	可供水量
			灌溉水平

2. Risk of extreme hydrological events globally and in China

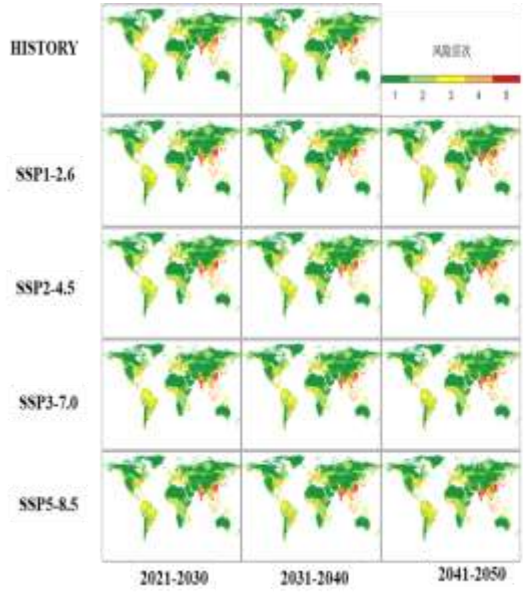
Risk assessment of extreme hydrological events globally

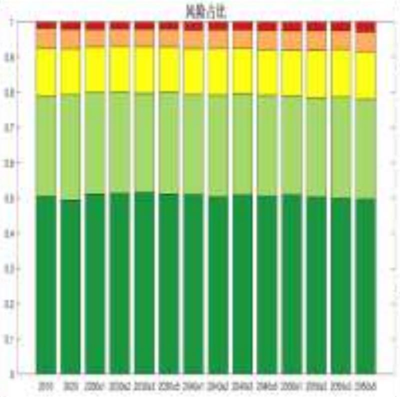
Global extreme rainfall and flood risk projections were conducted, and the high-risk areas are mainly located in East Asia, South-East Asia, Western Europe, Central Africa, Southeast North America, and Eastern South America.

The risk of SSP1-2.6 is relative low.

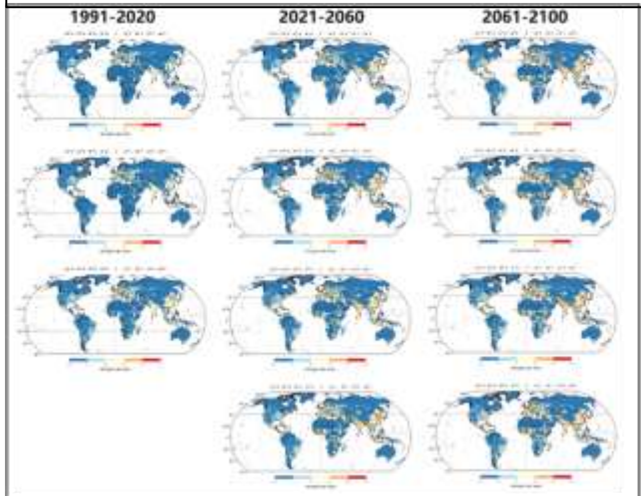
A global drought risk assessment was projected, and the spatial distribution of global high-risk areas for drought under the four scenarios is relatively consistent, with high-risk areas mainly located in densely populated and socio-economically developed regions, mainly in East Asia, South Asia, west-central Europe, and the eastern and southern coastal regions of the United States.

The SSP5-8.5 scenario has the highest risk.

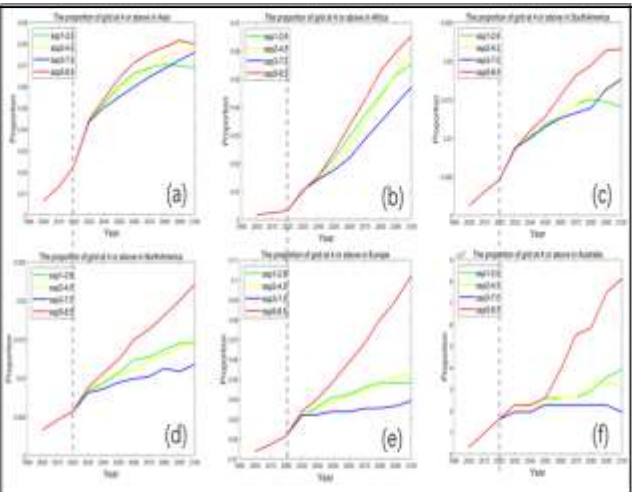




历史期暴雨洪涝灾害分布



SSP5-8.5情景下全球干旱灾害风险分布图



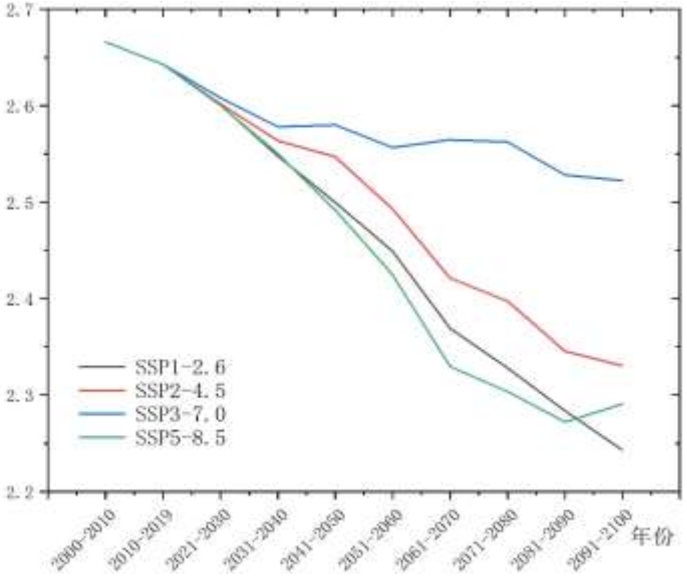
各大洲干旱高风险占比（十年平均）

2. Risk of extreme hydrological events globally and in China

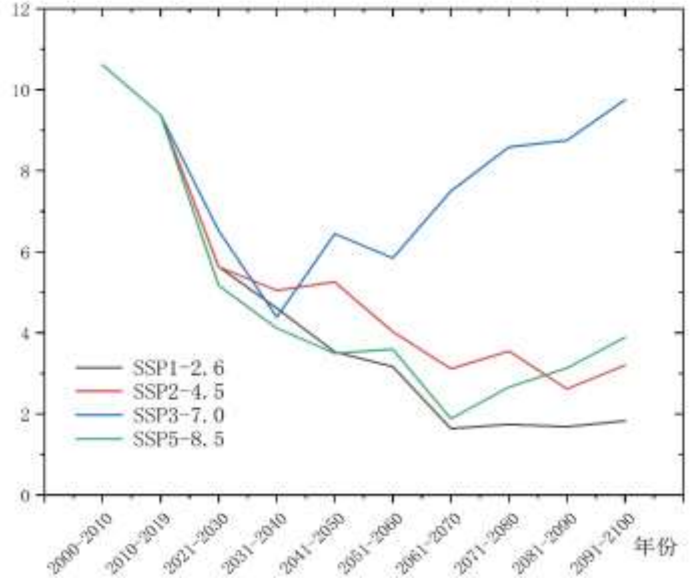
Risk evaluation of extreme hydrological events at the regional scale

The storm flood risk in China was projected. Based on the SSP scenario data, the proportion of hazardous and high-risk zones in the four future scenarios increased significantly, the exposure increased significantly, and the vulnerability decreased significantly.

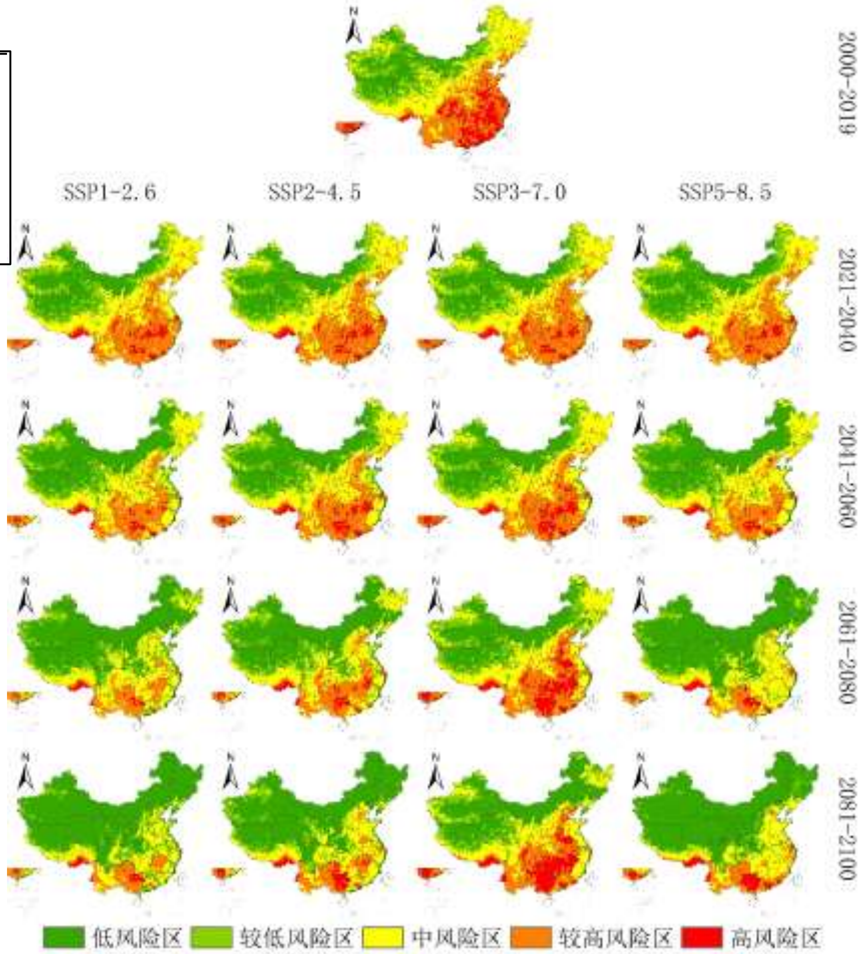
resulting in a significant reduction in the risk of storm flooding, and the high-risk zones were mainly concentrated in Jiangxi, Hunan, Anhui, Guangdong, and Guangxi.



Average risk



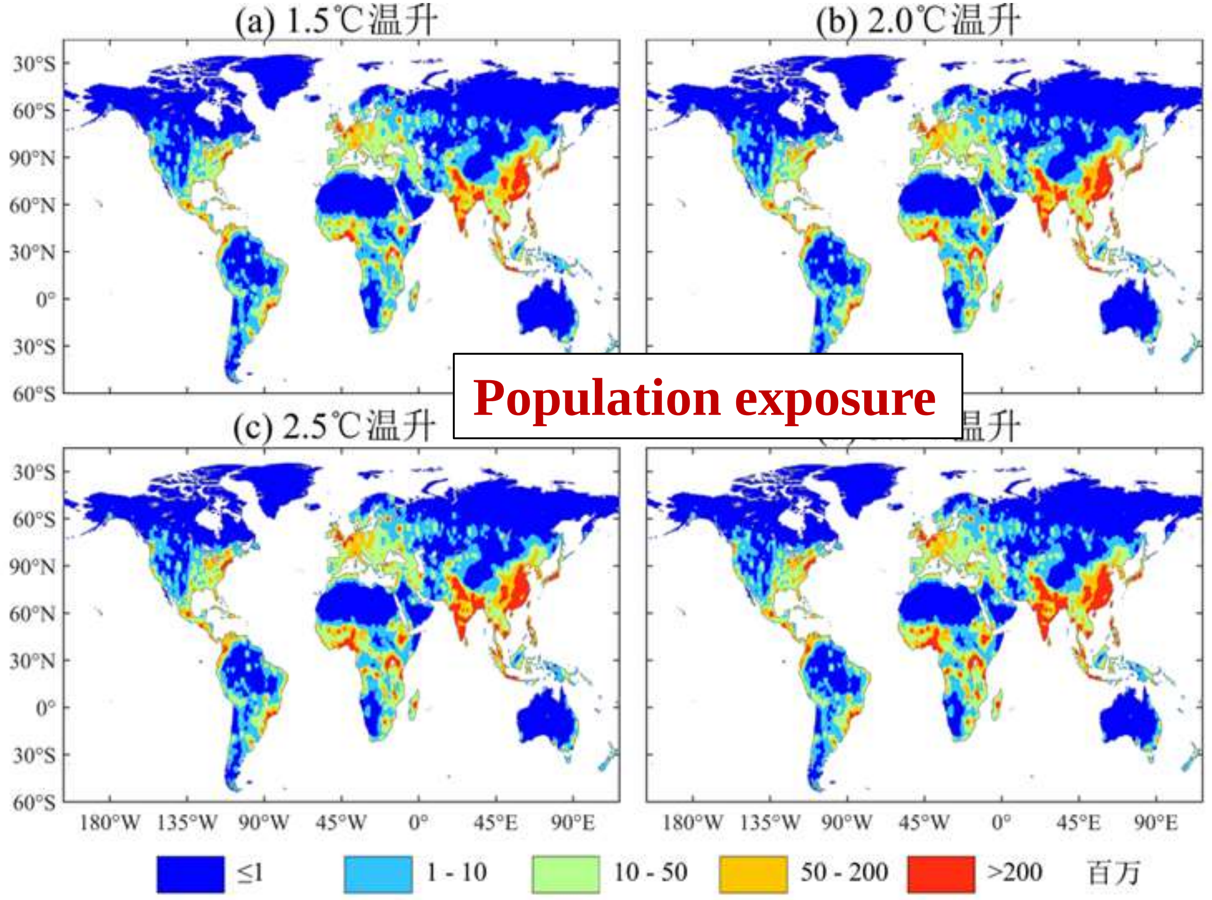
Percentage of high-risk areas



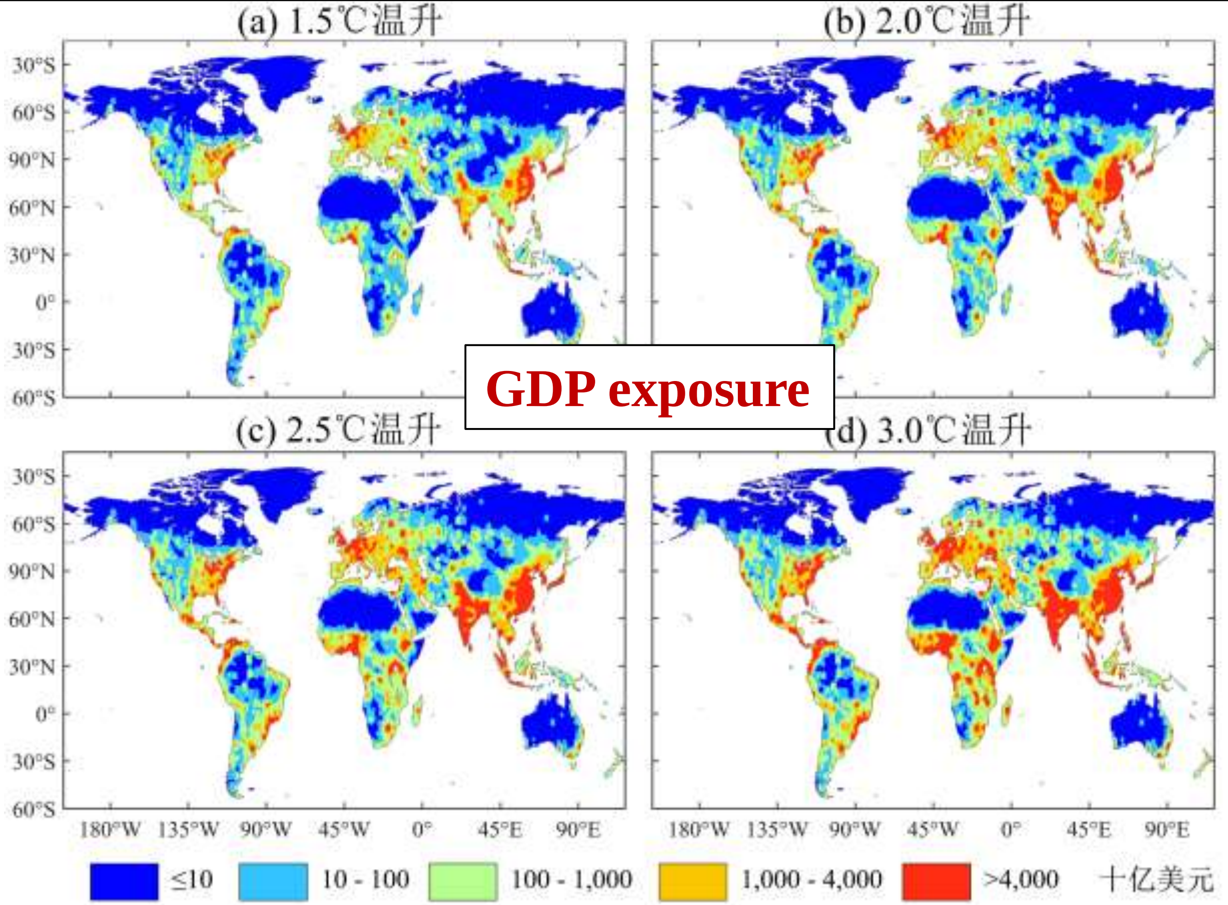
2. Risk of extreme hydrological events globally and in China

Projection of the risk of extreme flood events globally

As **the level of temperature rise increases**, more regions will have higher population and GDP exposures to extreme precipitation. Global warming will increase changes in **population and GDP exposure to extreme precipitation,** and the impacts will be greater with higher population and GDP exposure.



Population exposure

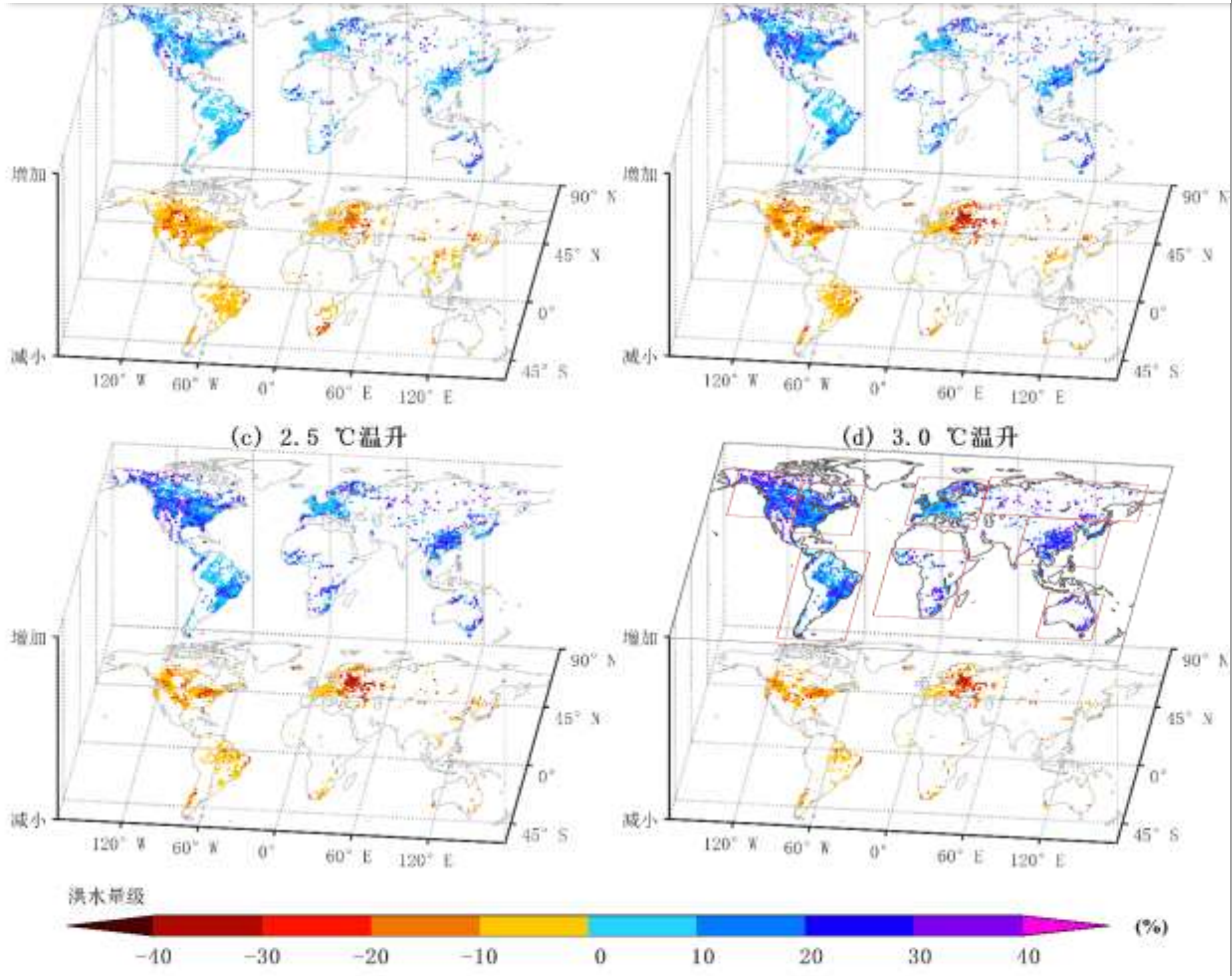


GDP exposure

2. Risk of extreme hydrological events globally and in China

Projection of the risk of extreme flood events globally

- **Changes in the magnitude of the 1 in 50 year flood based on multi-modal medians**



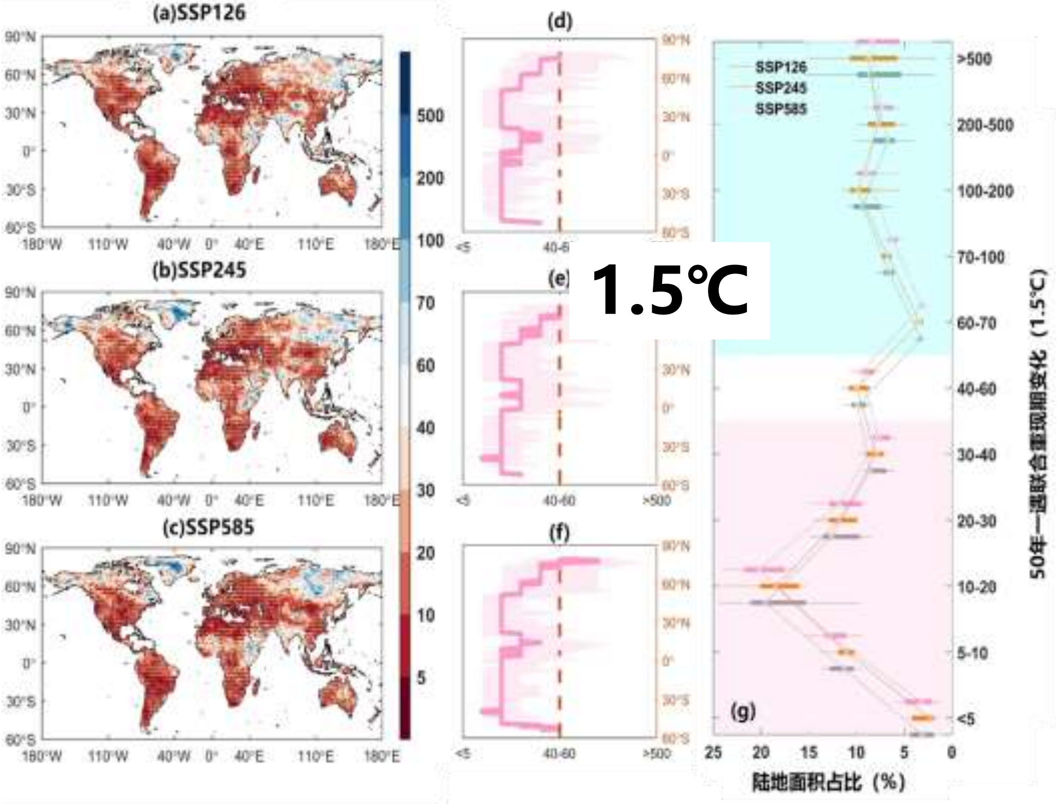
In the case of SSP245, the response of floods under different levels of temperature rise and changes in global flood pressure, compared to the reference period (1985-2014) as the level of temperature rise increases:

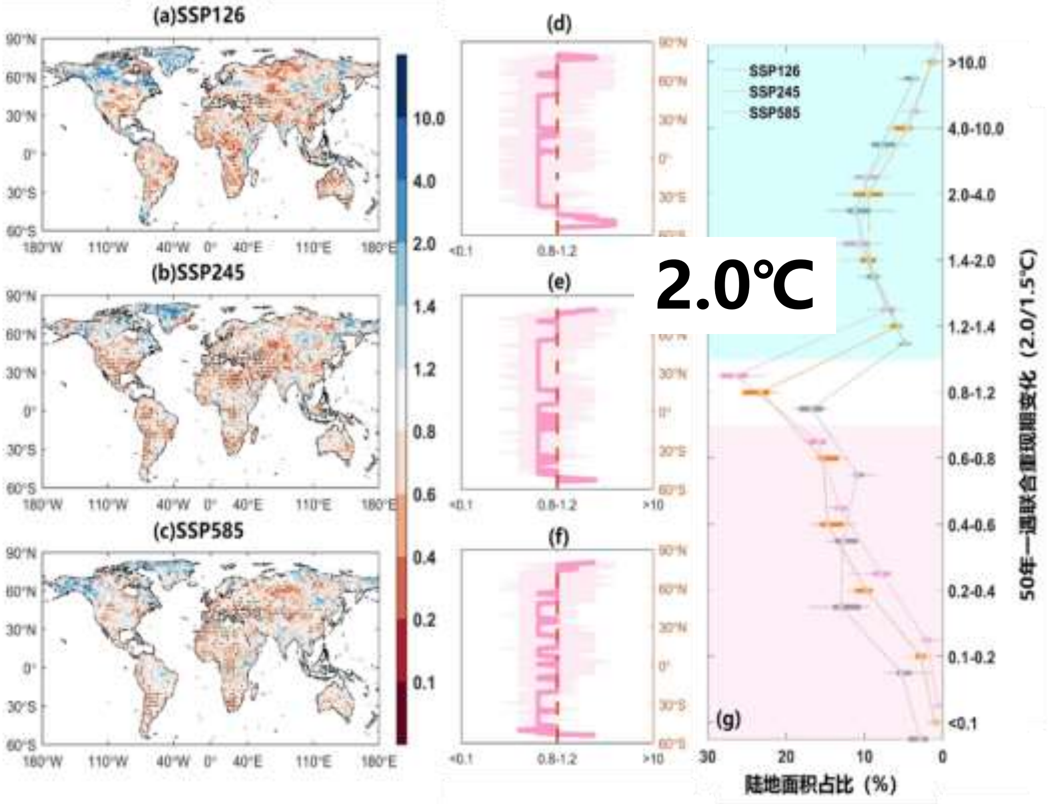
- **Flood magnitude will continue to increase in most basins and the number of such basins increases;**
- **Flood magnitudes increase in 52% of basins globally under 1.5° C temperature rise level; while 81% of basins globally increase in magnitude under 3.0° C temperature rise level ;**
- **The average increase in flood magnitude for basins in Africa, south-east Asia, Australia and South America under a 3.0° C temperature rise level is 31%, 26%, 37% and 16%, respectively.。**

2. Risk of extreme hydrological events globally and in China

Projecting risk of extreme drought events globally

In regions with worsening drought conditions, the probability of a 1-in-50-year drought event increases significantly with warming. Under a 1.5° C warming scenario, about 88% of the continent would experience a more severe drought risk; under a 2.0° C warming scenario, the probability of a drought event would double over 67% of the region.

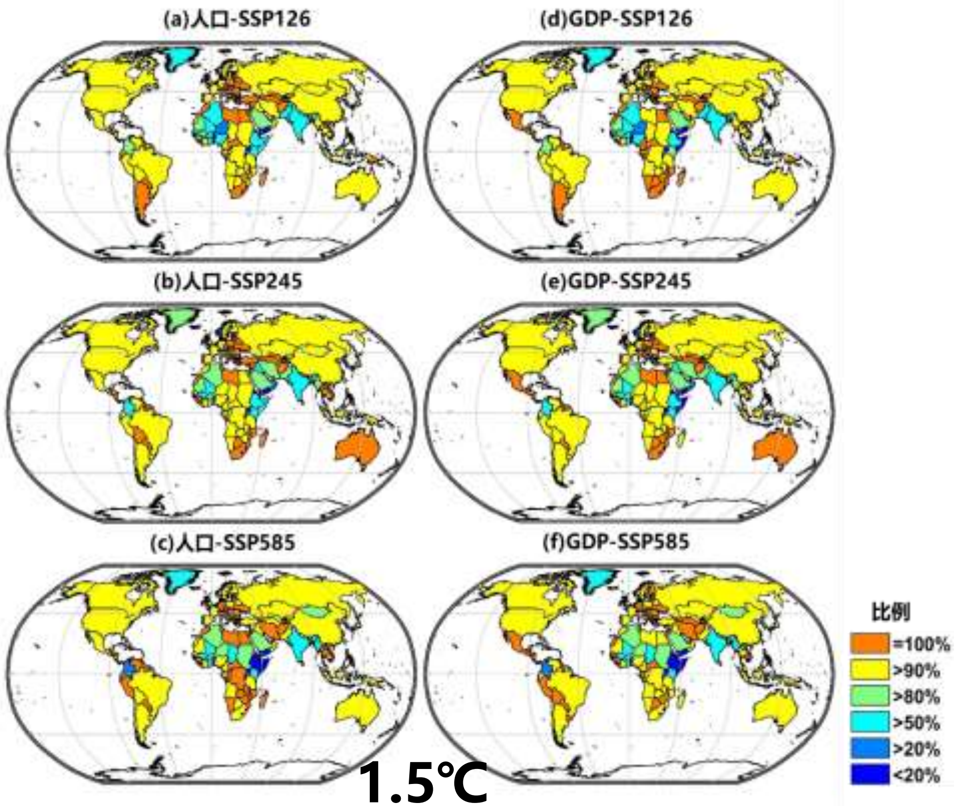




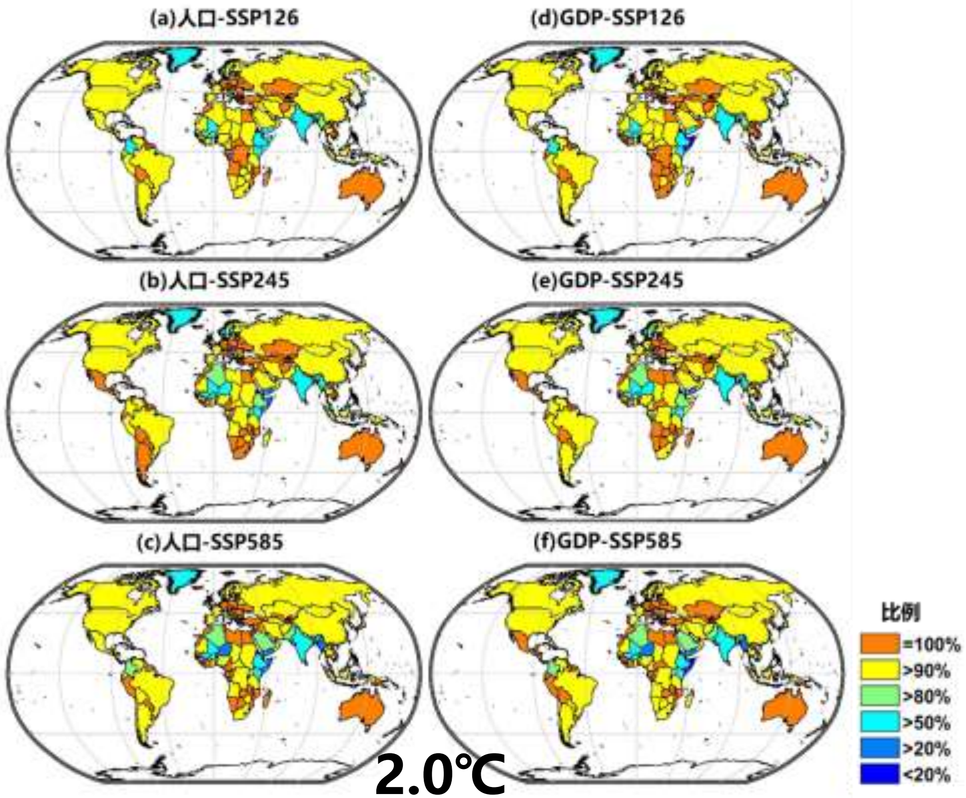
2. Risk of extreme hydrological events globally and in China

Projecting risk of extreme drought events globally

Globally, the proportion of population and GDP exposed to increased drought **risk is higher** under different SSP scenarios. Globally, **67 countries** would have 100% exposure of population and GDP **at 1.5° C.** A **2.0° C** temperature increase would result in **17 more** countries with 100% exposure of population and GDP, reaching **84 countries**.



1.5℃

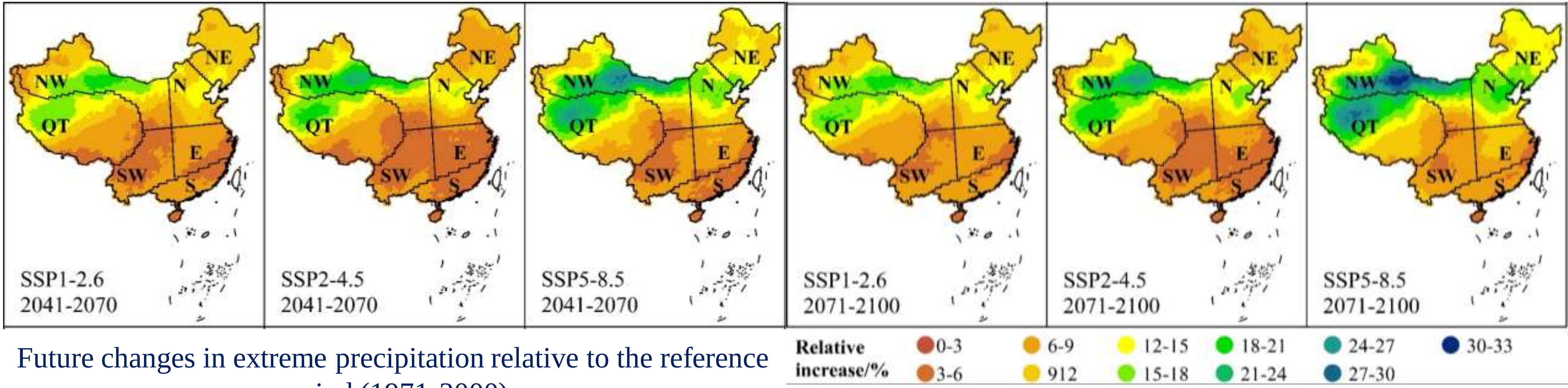


2.0℃

2. Risk of extreme hydrological events globally and in China

Extreme precipitation

Extreme precipitation has a similar pattern of change as average precipitation, i.e., extreme precipitation in China is likely to increase in the future, with a national average increase of about 10%. The relative increase in extreme precipitation in north-western and northern China is greater than in other regions.

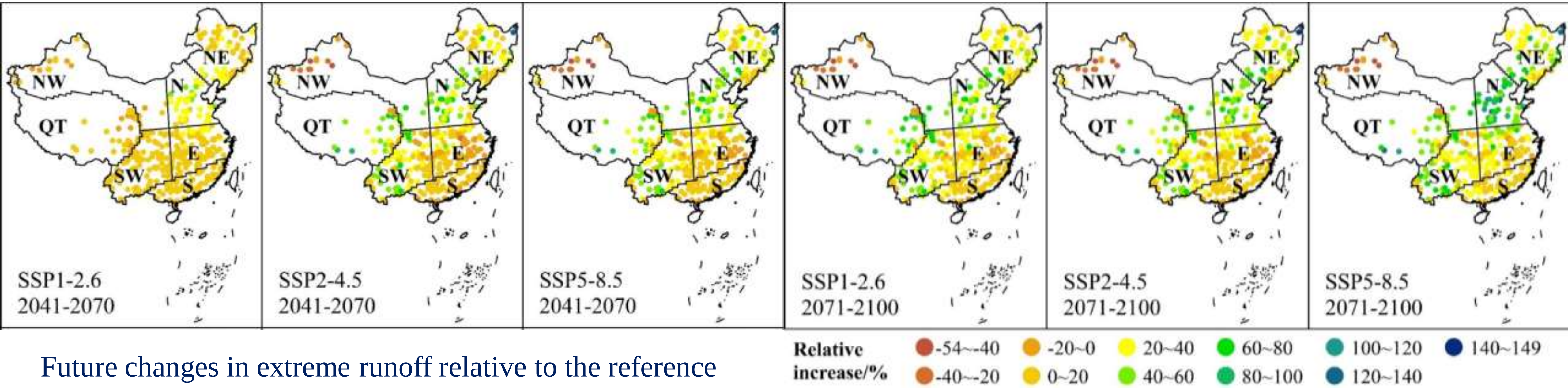


Future changes in extreme precipitation relative to the reference period (1971-2000)

2. Risk of extreme hydrological events globally and in China

Extreme runoff

The future average runoff from most river basins in China is on the increase; the increase will gradually increase as the level of greenhouse gas emissions increases. The relative increase in average runoff in North China, the Tibetan Plateau, and Southwest China is greater than in other regions. The average runoff in some basins in the north-west and east of the country shows a decreasing trend.

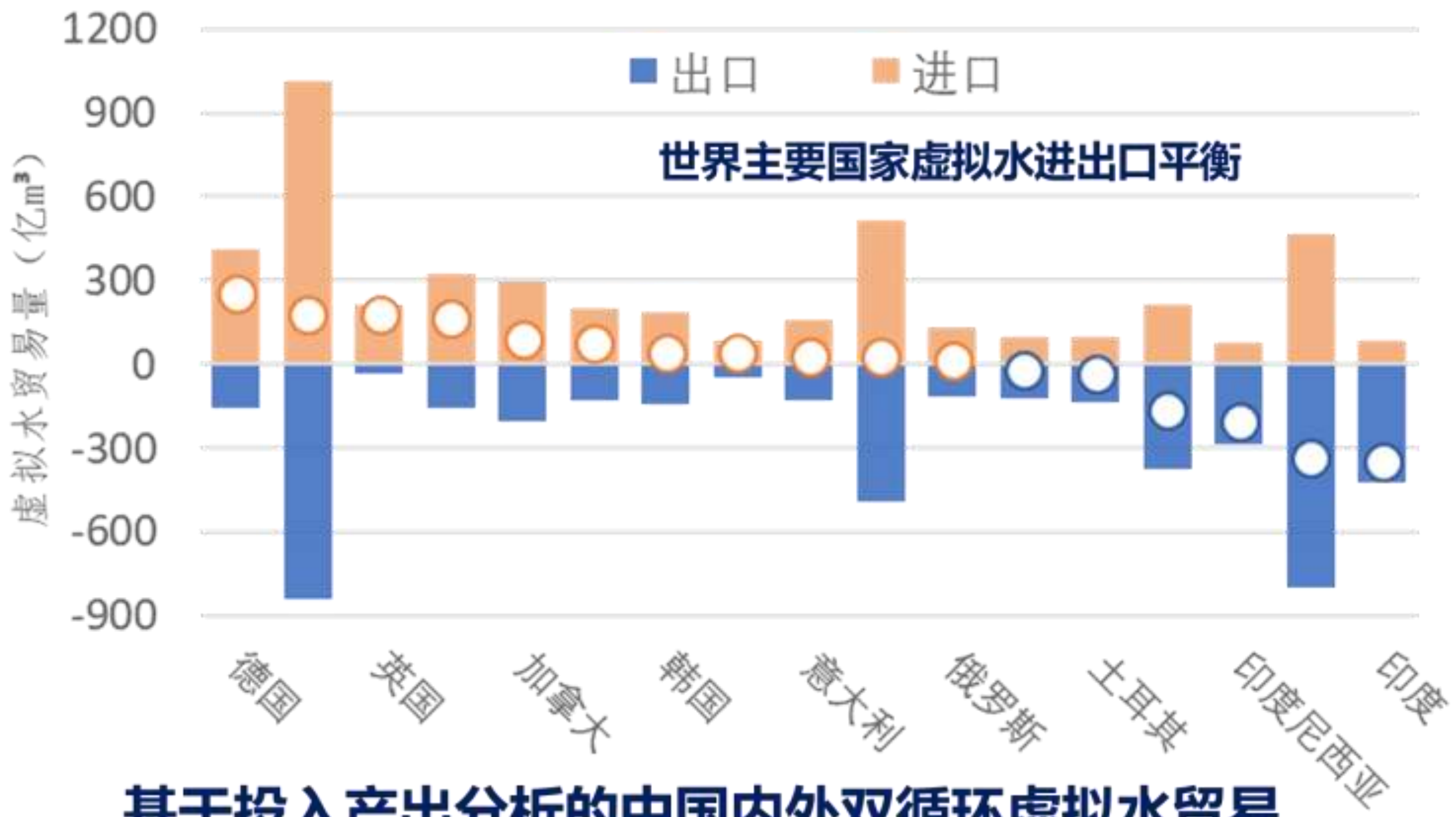


Future changes in extreme runoff relative to the reference period (1971-2000)

Outlines

3. Response to the risk of extreme hydrological events based on the theory of virtual water trade

The main international virtual water cycle flows between the US-China-EU countries from 2005-2018; in China's foreign and US trade, China imports virtual water through agriculture and exports virtual water through manufacturing; China's net exports of virtual water have been decreasing year by year, with particular attention to be paid to extreme flood and drought years.



基于投入产出分析的中国内外双循环虚拟水贸易

Remarks

Insights — New insights into the past and future evolution of the global water cycle

- Multi-year average of global water vapour, precipitation, evaporation and runoff
- → Interdecadal changes
  Runoff and attribution of extreme events

Solutions — Global Risks of Extreme Hydrological Events and China's Adaptation Measures

- Static socio-economic risk management
- → Risk of extreme events of socio-economic change
  Adaptative measures considering global virtual water trade

Thank you for your attention !