Side Event of XVIII World Water Congress
How Integrated Water Resources Management (IWRM) Adapt to Climate Change and Economic Development

SUN YAT-SEN UNIVERSITY

Incorporating Temporal Changes into Flood Loss Estimations

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Introduction

- Floods are one of the most devastating natural disasters around the world

https://www.12371.cn/2021/08/16/VIDE1629072721063885.shtml

1998 Flood of the Yangtze River Basin

Introduction

- Floods are one of the most devastating natural disasters around the world

2023 Flood of the Hai River Basin

Introduction

- Engineering and non-engineering measures for flood control

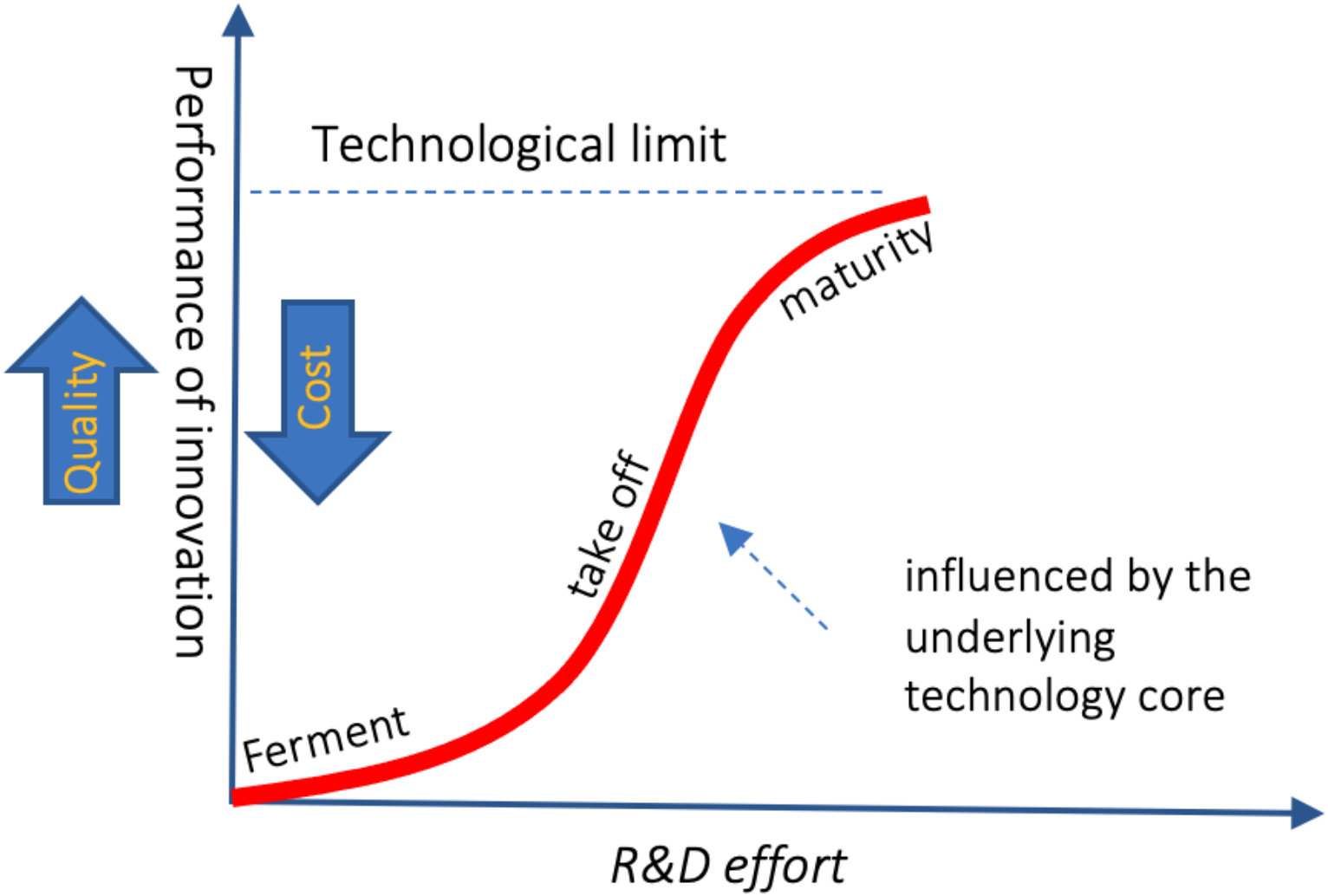
https://zhuanlan.zhihu.com/p/557489415

https://blog.csdn.net/digihail2016/article/details/110558272

Introduction

- China Flood and Drought Disaster Prevention Bulletin since 2006

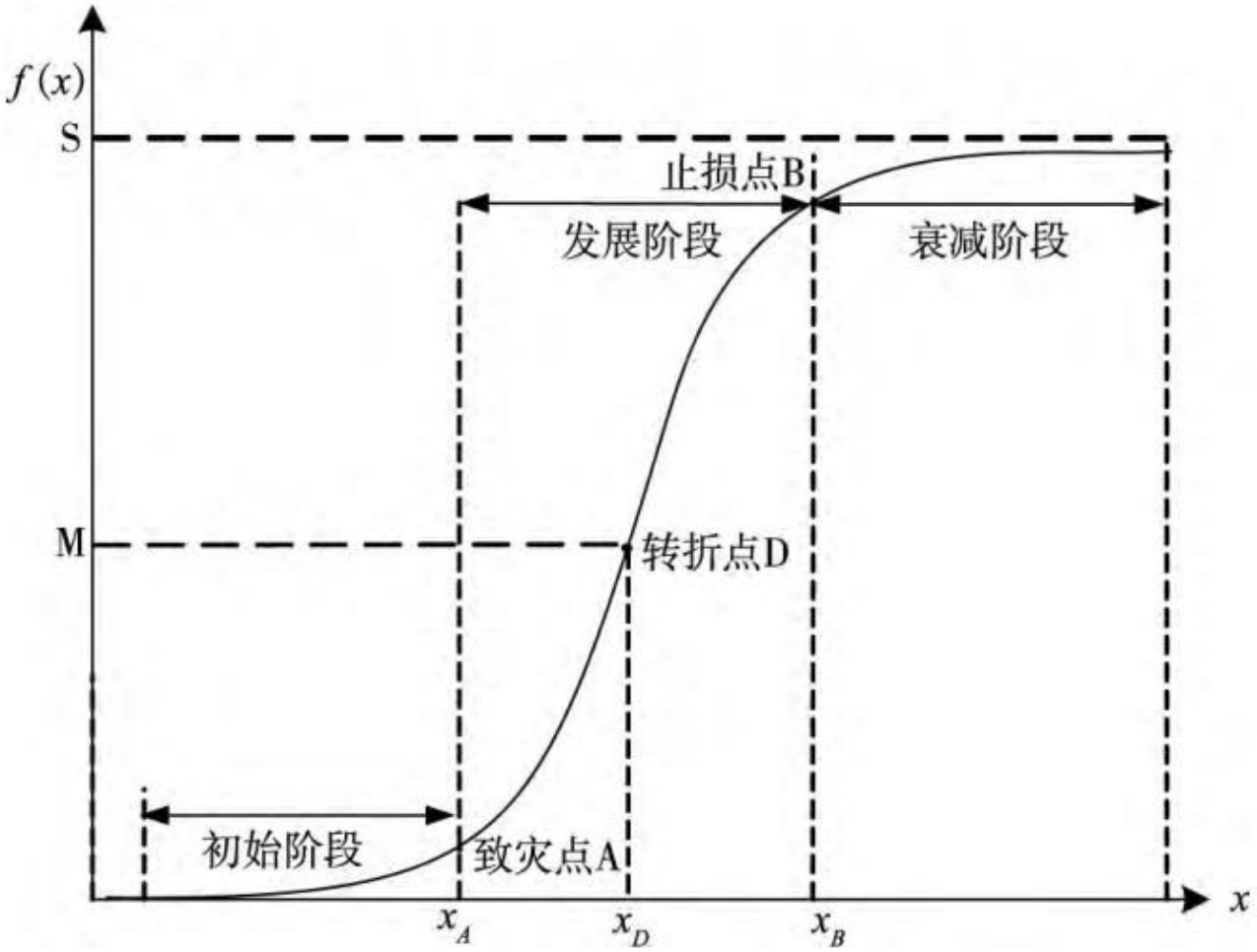
The famous S curve



https://www.the-waves.org/2022/03/13/innovation-s-curve-episodic-innovation-evolution/

Innovation S-curve refers to the formation and growth of innovations reaching maturity. As human beings, upon birth, innovations keep evolving through stages. The evolution takes place because of (i) the advancement of the underlying technology core, (ii) progressive revealing of user requirements, (iii) unfolding externalities, (iv) availability of complementary technologies, and (v) competition

S curve for flood loss estimation

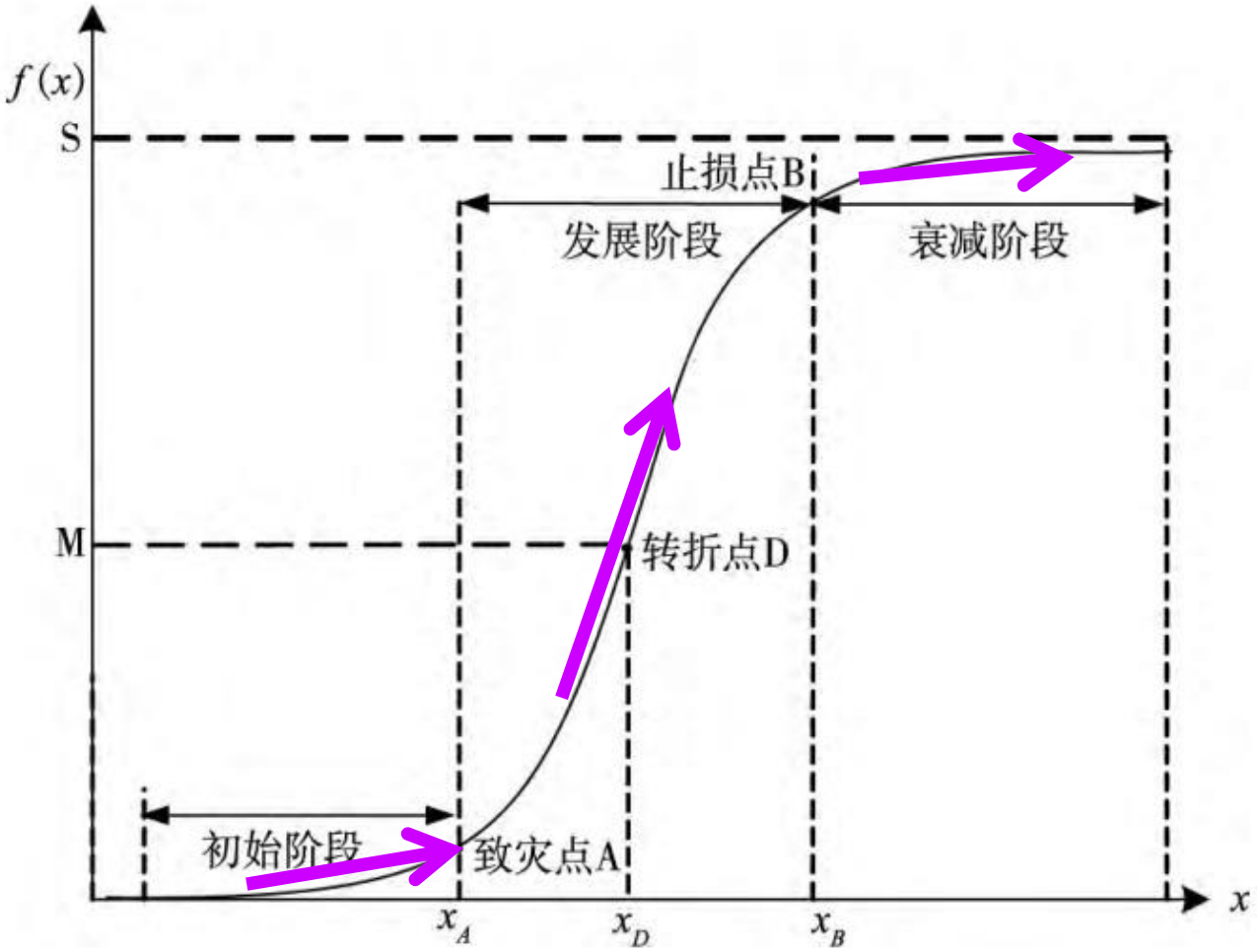


Flood loss

Flooding risk drivers

[Chen et al.， 2015、2017]

S curve for flood loss estimation



Flood loss

Flooding risk drivers

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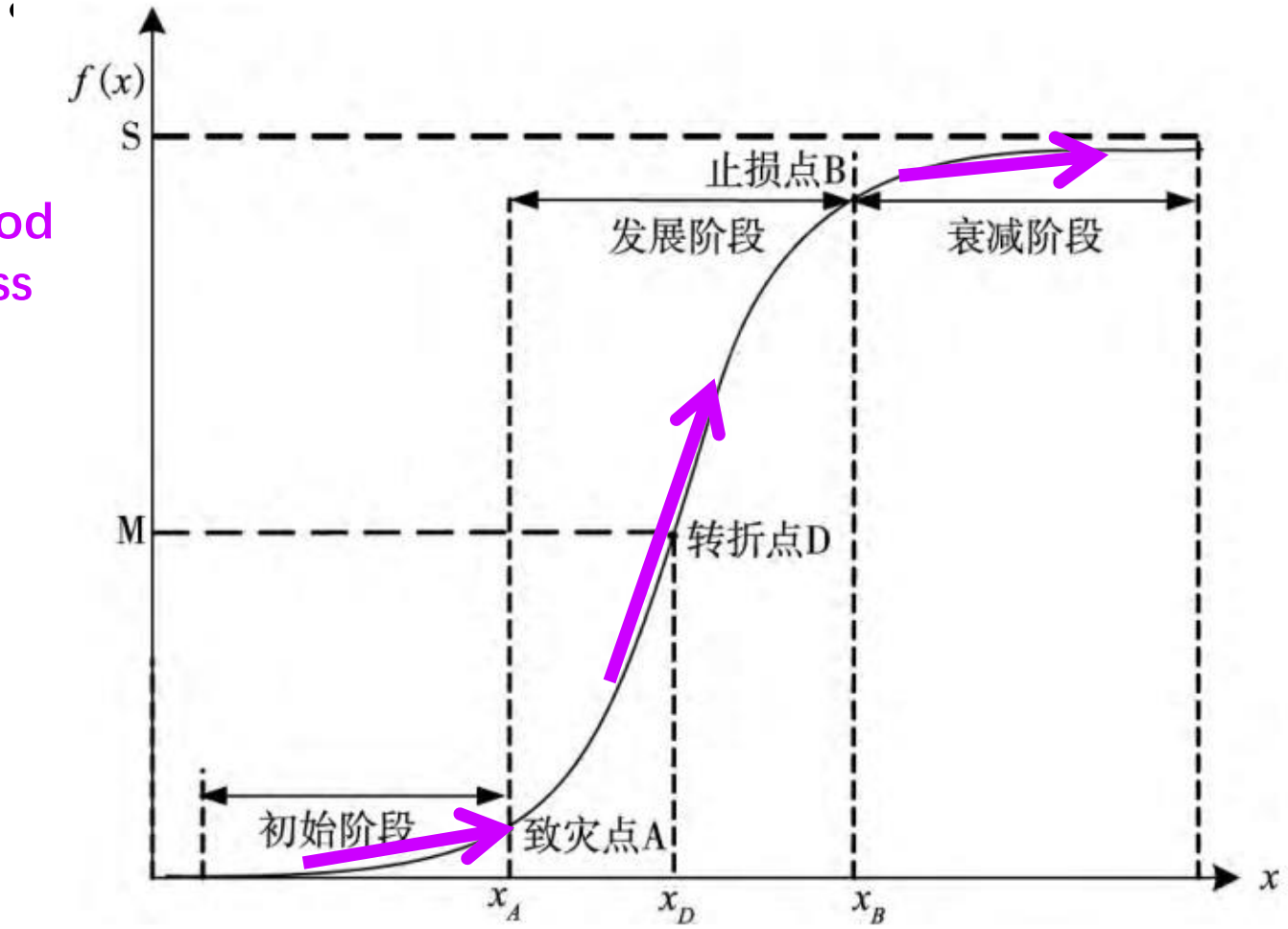
S curve for flood loss estimation

Flood loss



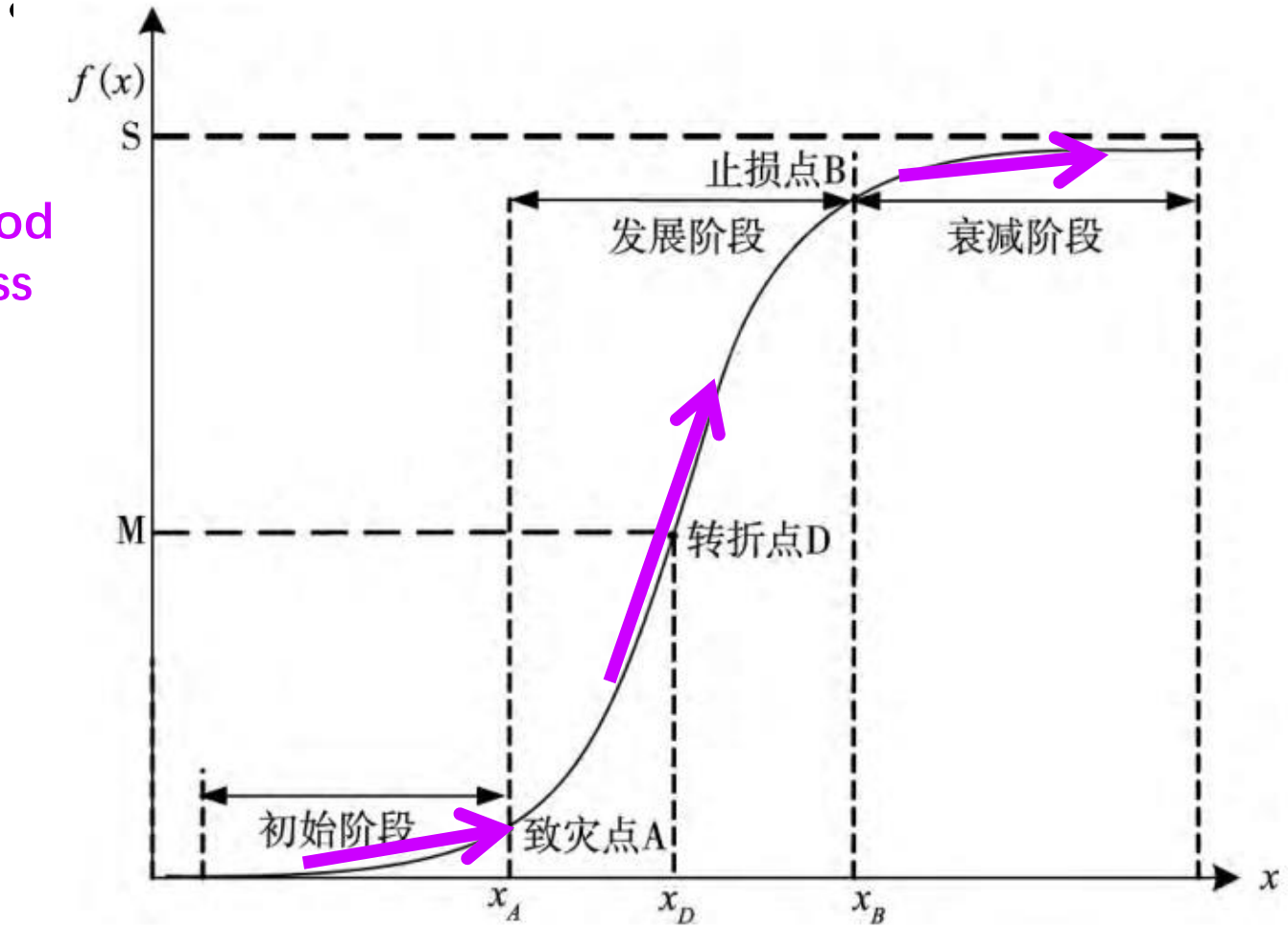
Flooding risk drivers

[Chen et al., 2015、2017]

名称	表达式
Boltzmann	$y = A - \frac{A}{1 + e^{(x-c)/k}}$
Logistic	$y = \frac{A}{1 + e^{-k(x-c)}}$
Gompertz	$y = Ae^{-e^{-k(x-c)}}$

[Li et al., 2020a、2020b]

S curve for flood loss estimation



- Non-stationarity of the S curve for flood loss estimation
  - Economic and social developments
  - Engineering measures
  - Non-engineering measures

[Chen et al., 2015、2017]

[Li et al., 2020a、2020b]

Method development

- Three functions

名称	表达式
Boltzmann	$y = A - \frac{A}{1 + e^{(x-c)/k}}$
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- Three parameters
  - A for magnitude
  - k for shape
  - c for location

[Li et al.，2020a、2020b]

Method development

- Temporal changes
  - The incorporation of time into A, k and c to account for “non-stationarity”

$$L(x,t)=\begin{cases}(A_0+A_1t)-\dfrac{A_0+A_1t}{1+e^{(x-c)/k}}\\ A-\dfrac{A}{1+e^{(x-c)/(k_0+k_1t)}}\\ A-\dfrac{A}{1+e^{(x-(c_0+c_1t))/k}}\end{cases}$$

Boltzmann function

$$L(x)=\begin{cases}\dfrac{A_0+A_1t}{1+e^{-k(x-c)}}\\ \dfrac{A}{1+e^{-(k_0+k_1t)(x-c)}}\\ \dfrac{A}{1+e^{-k(x-(c_0+c_1t))}}\end{cases}$$

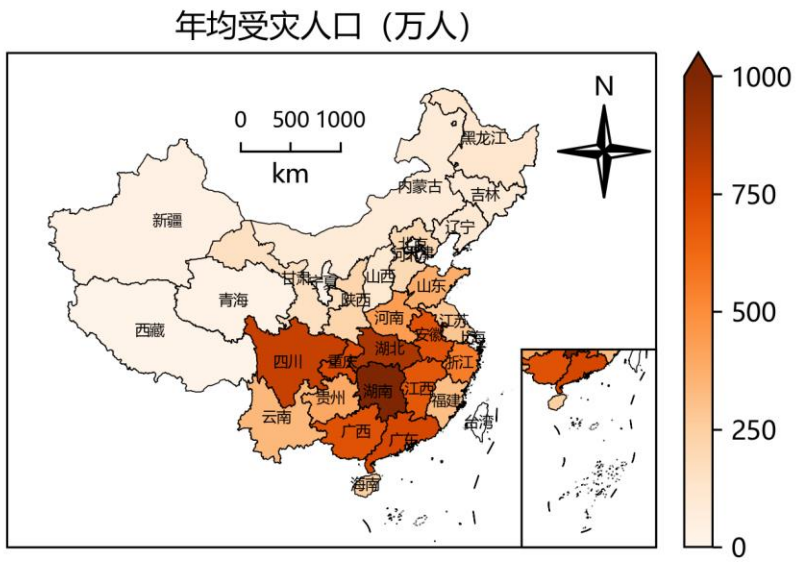
Logistic function

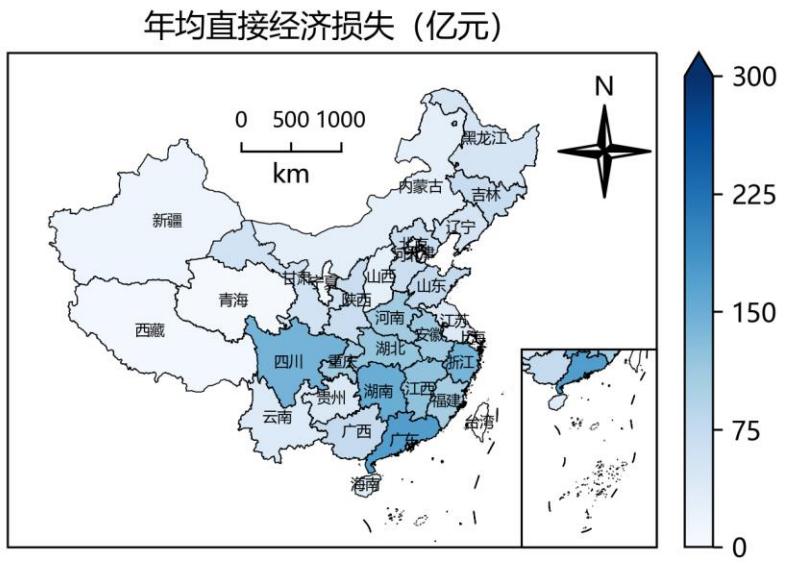
$$L(x)=\begin{cases}(A_0+A_1t)e^{-e^{-k(x-c)}}\\ Ae^{-e^{-(k_0+k_1t)(x-c)}}\\ Ae^{-e^{-k(x-(c_0+c_1t))}}\end{cases}$$

Gompertz function

Data description

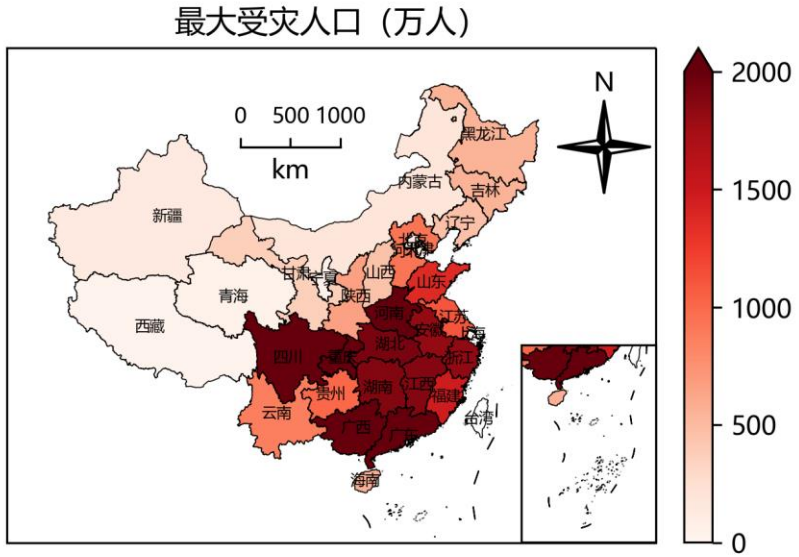
Multi-annual mean flood-affected population

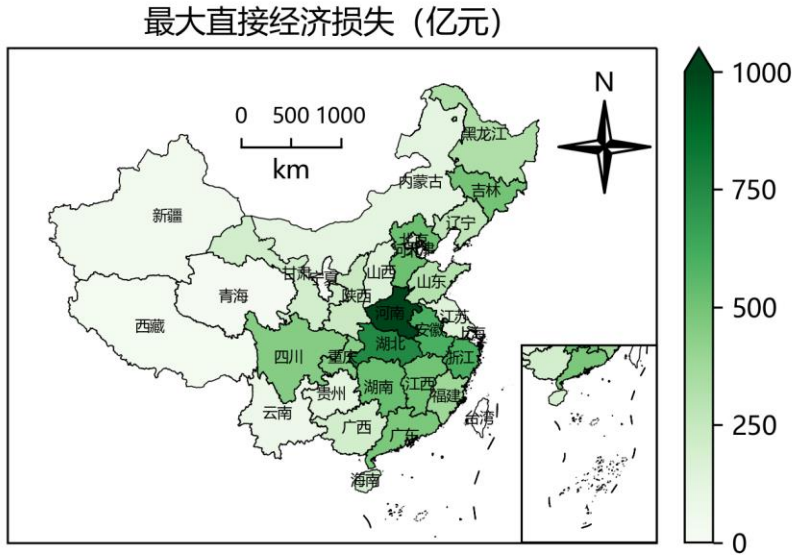




Multi-annual mean direct economic loss

Maximum annual flood-affected population

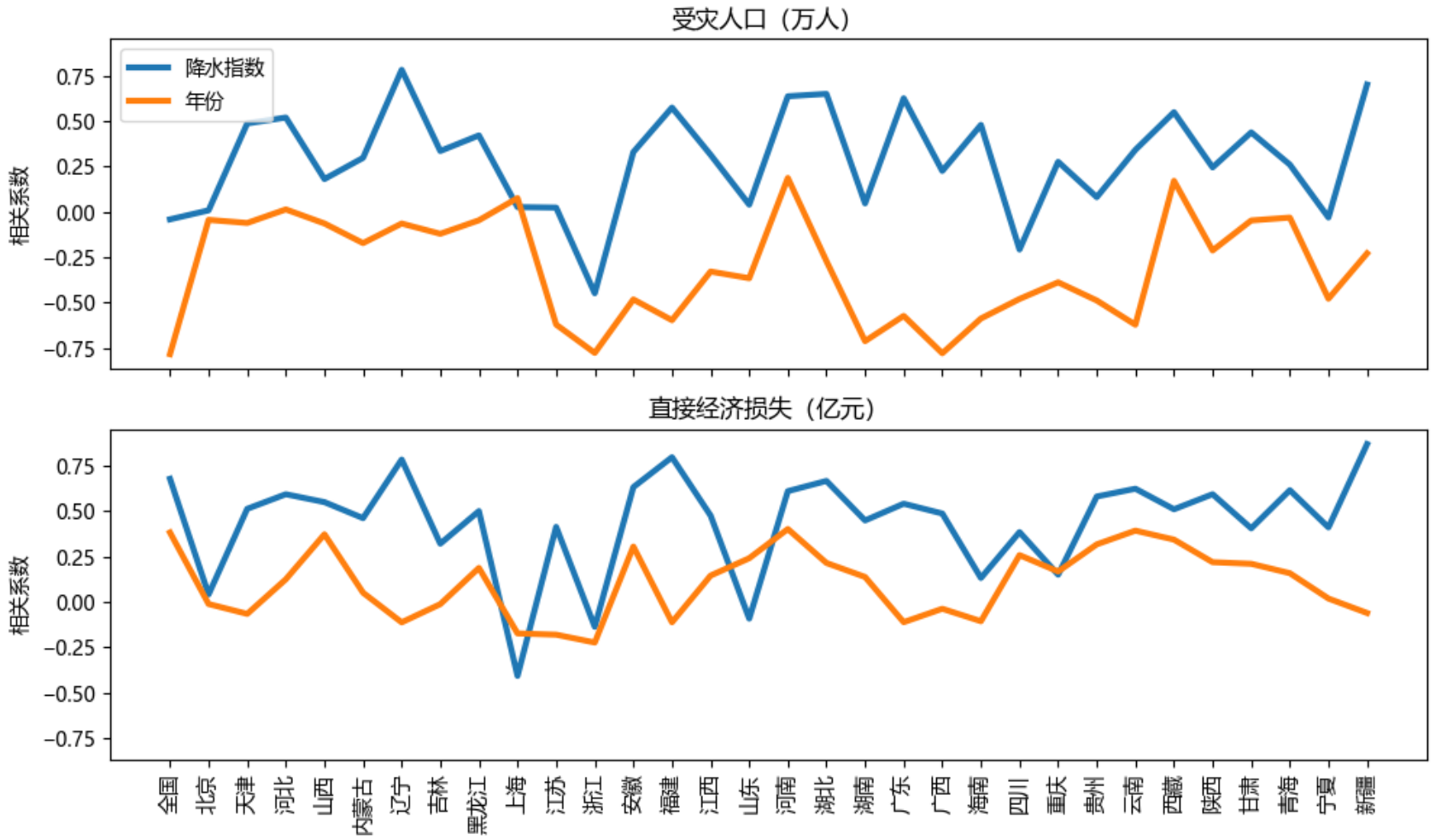




Maximum annual direct economic loss

Results

- Correlation analysis for flood-affected population

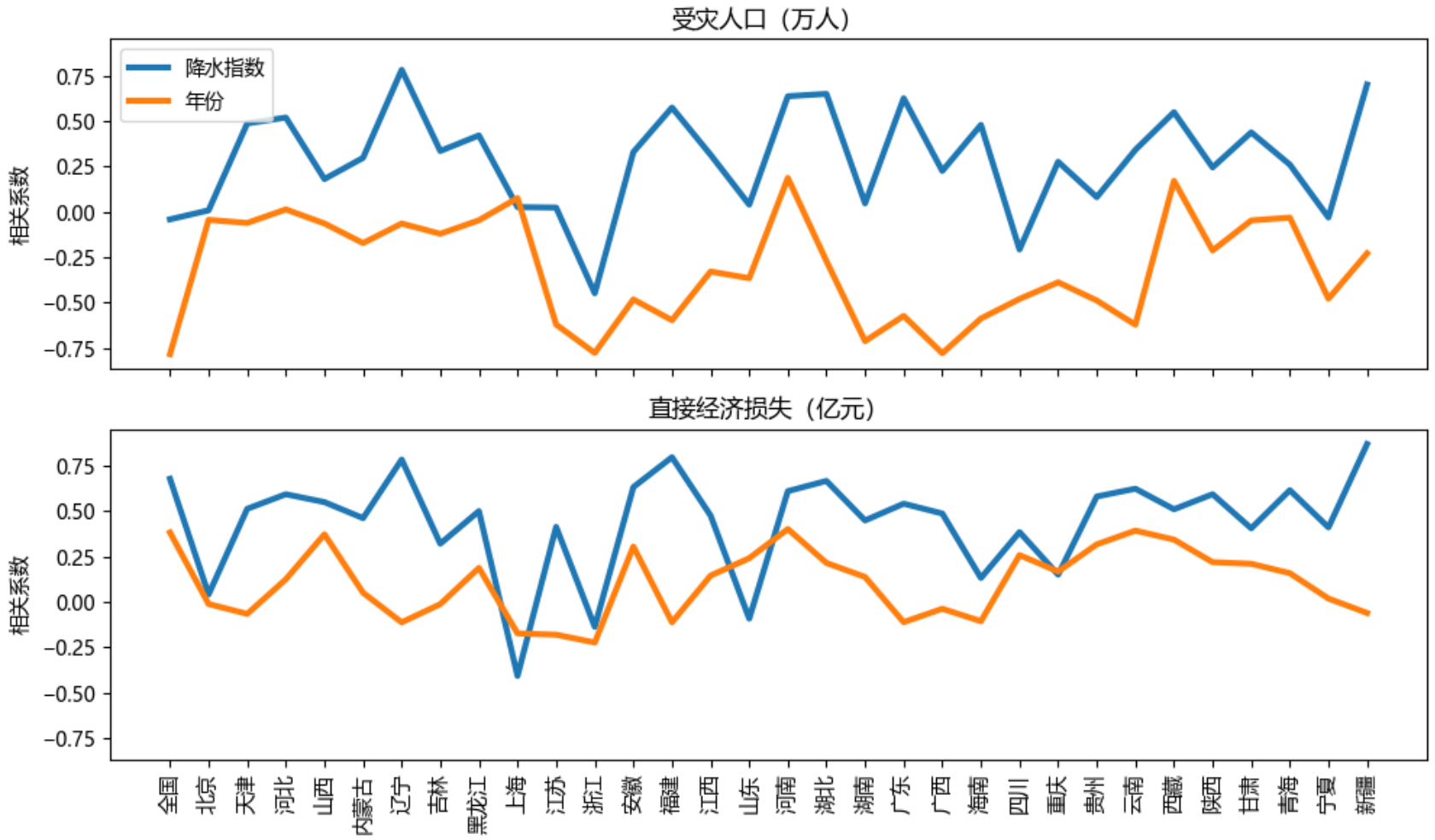


Positively correlated with SPI

Negatively correlated with time

Results

- Correlation analysis for direct economic loss

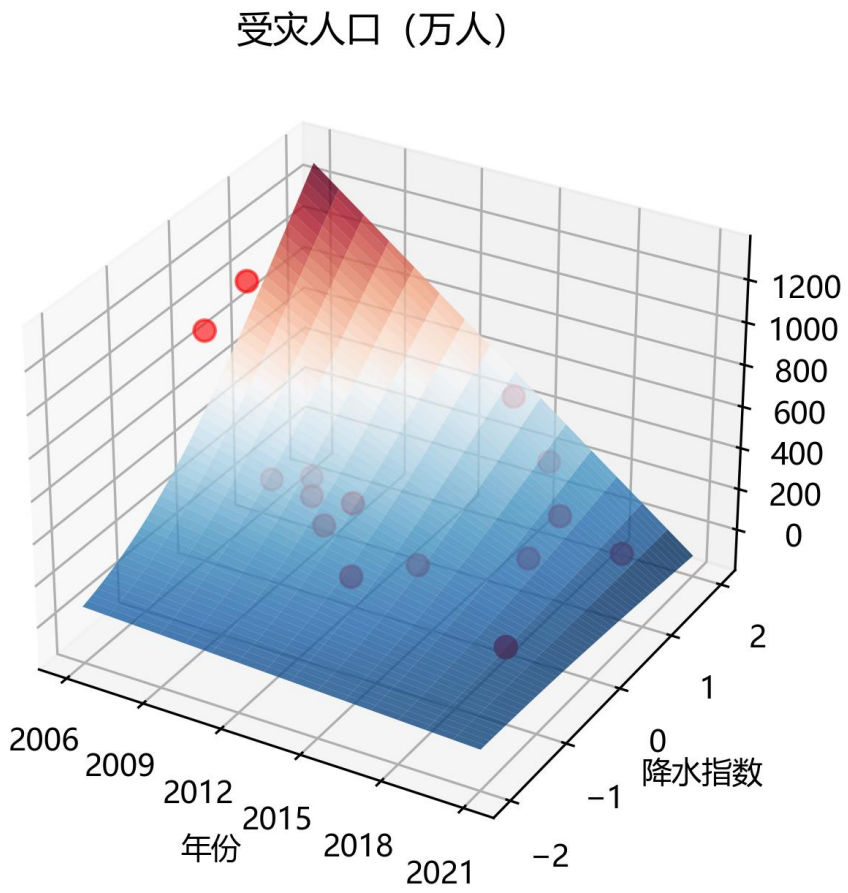


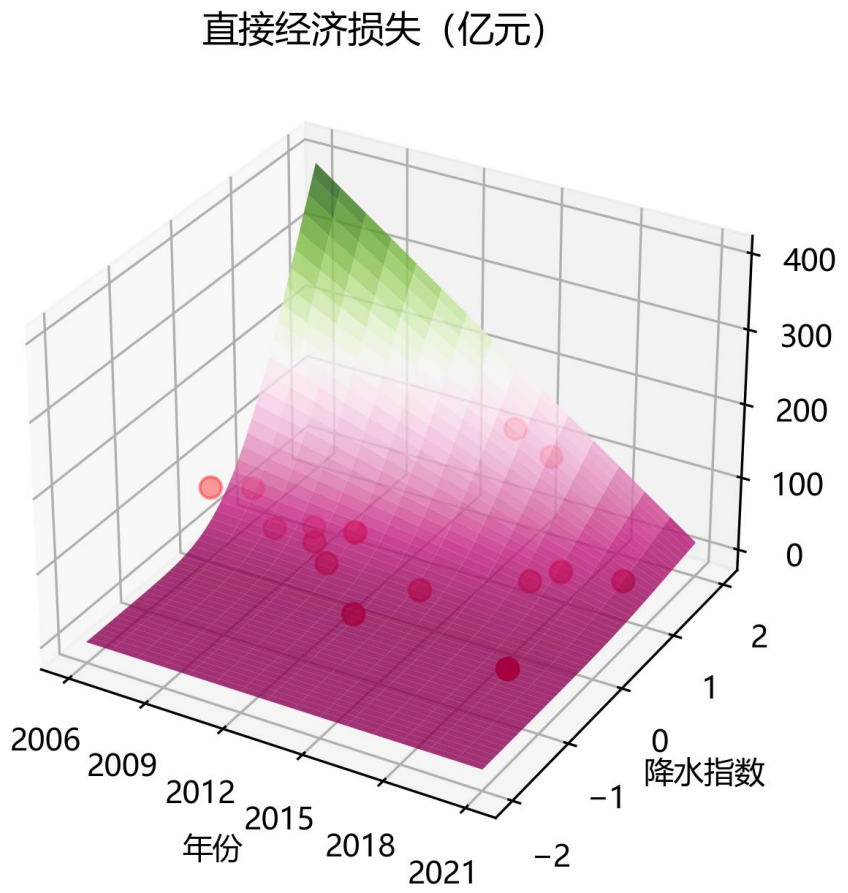
Positively correlated with SPI

Positively correlated with time

Results

- Jiangsu Province (2006-2021): 3-D scatter plot and response surface



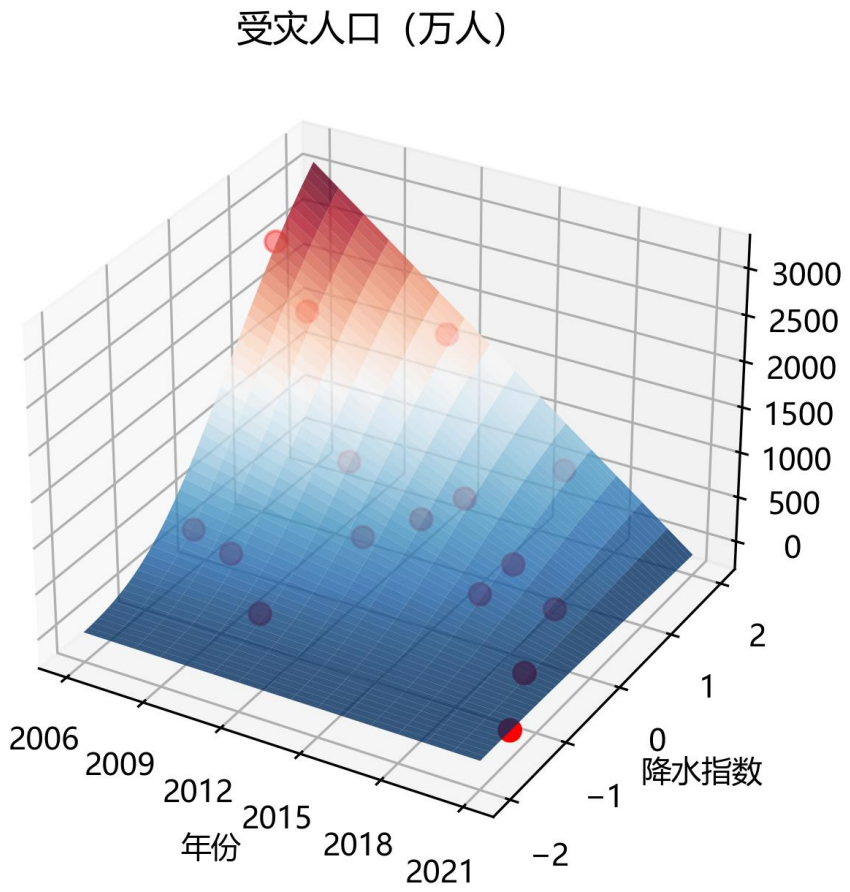


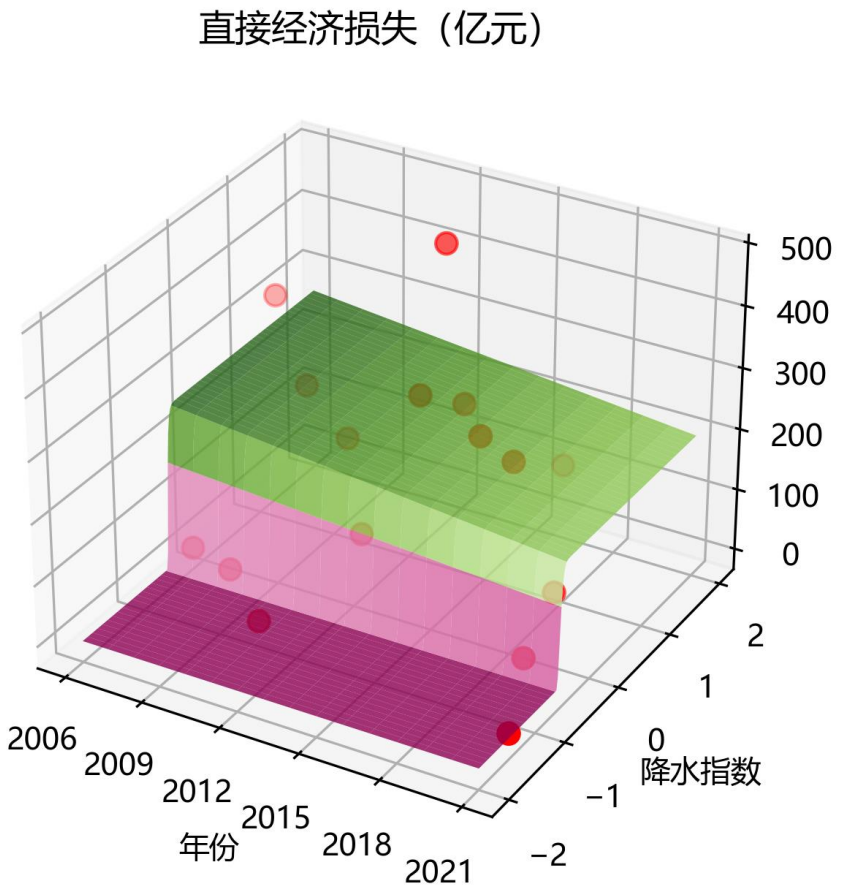
x-axis: time
y-axis: SPI
z-axis: flood-affected population (left) and direct economic loss (right)

Steady decease of flood-affected population and direct economic loss with time

Results

- Guangdong Province (2006-2021): 3-D scatter plot and response surface



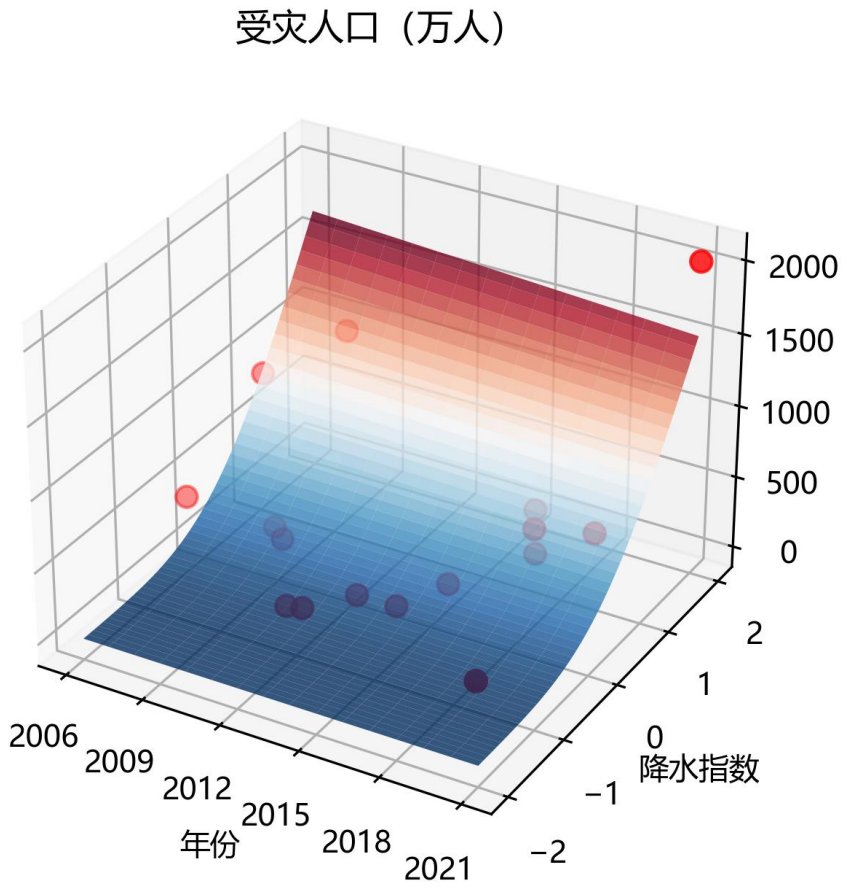


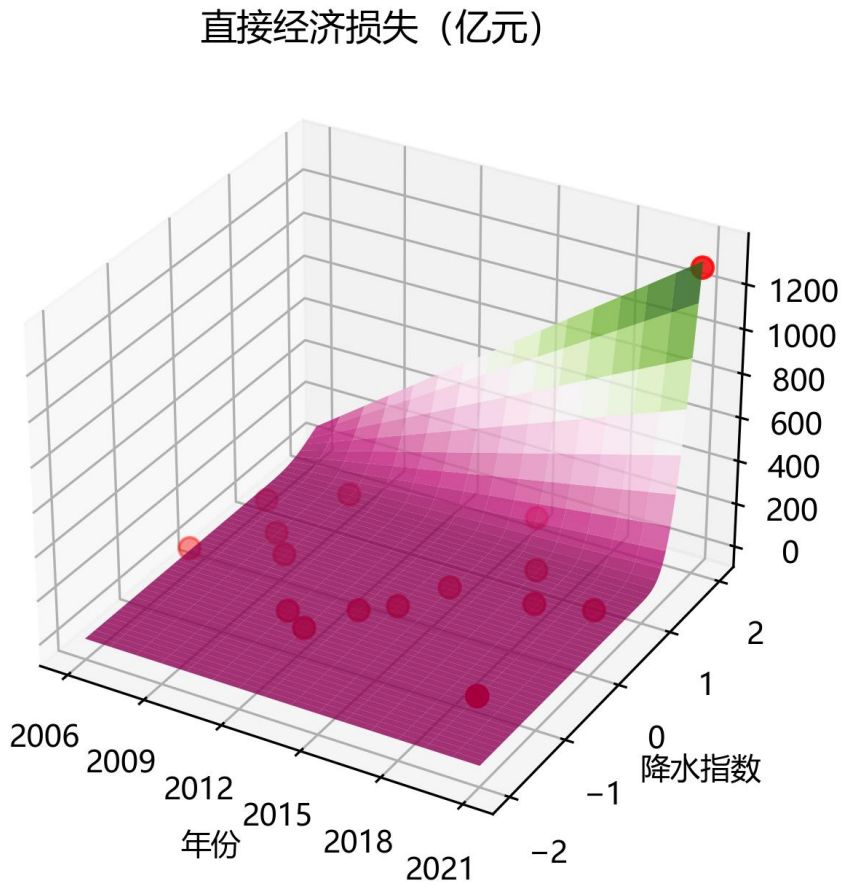
Steady decease of flood-affected population with time

Gradual decease of flood-affected population and direct economic loss with time

Results

- Henan Province (2006-2021): 3-D scatter plot and response surface

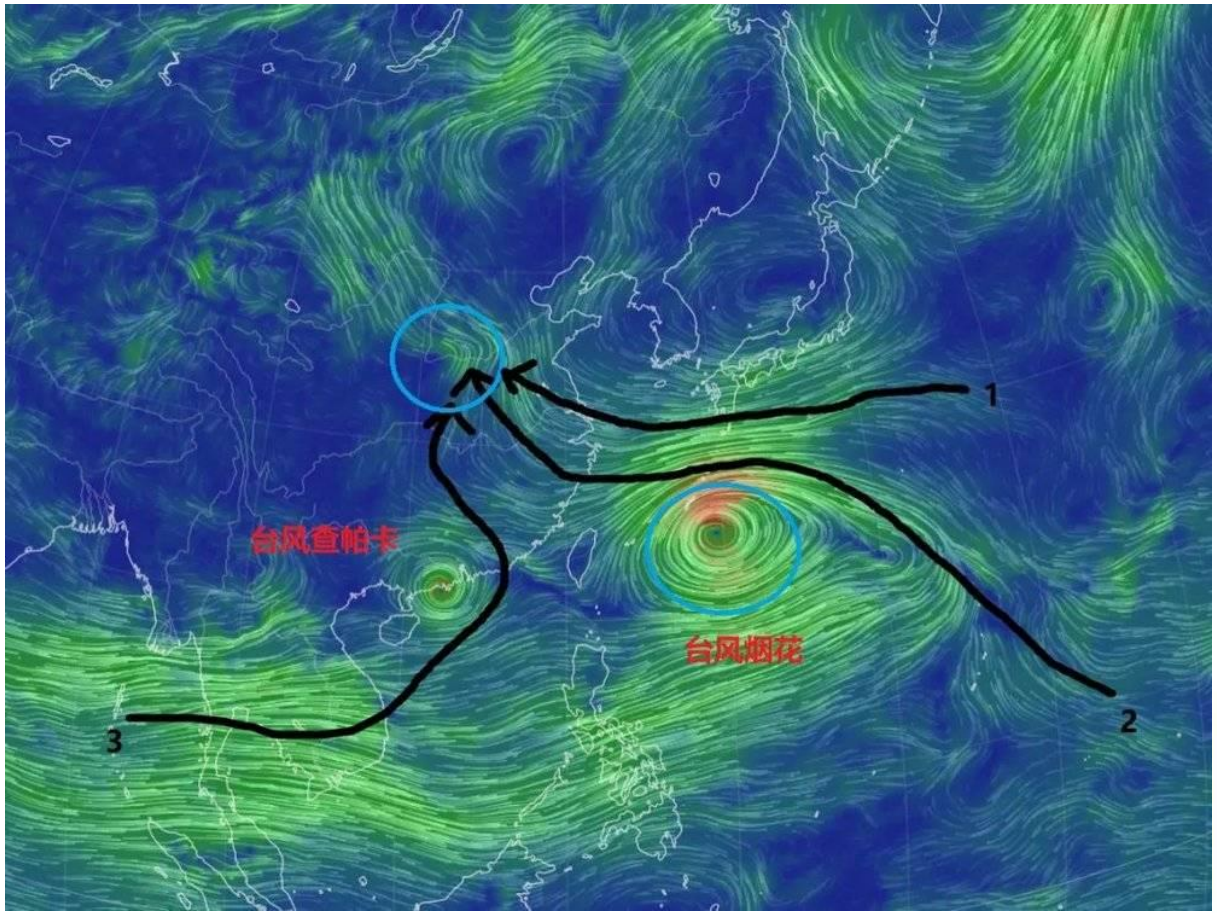


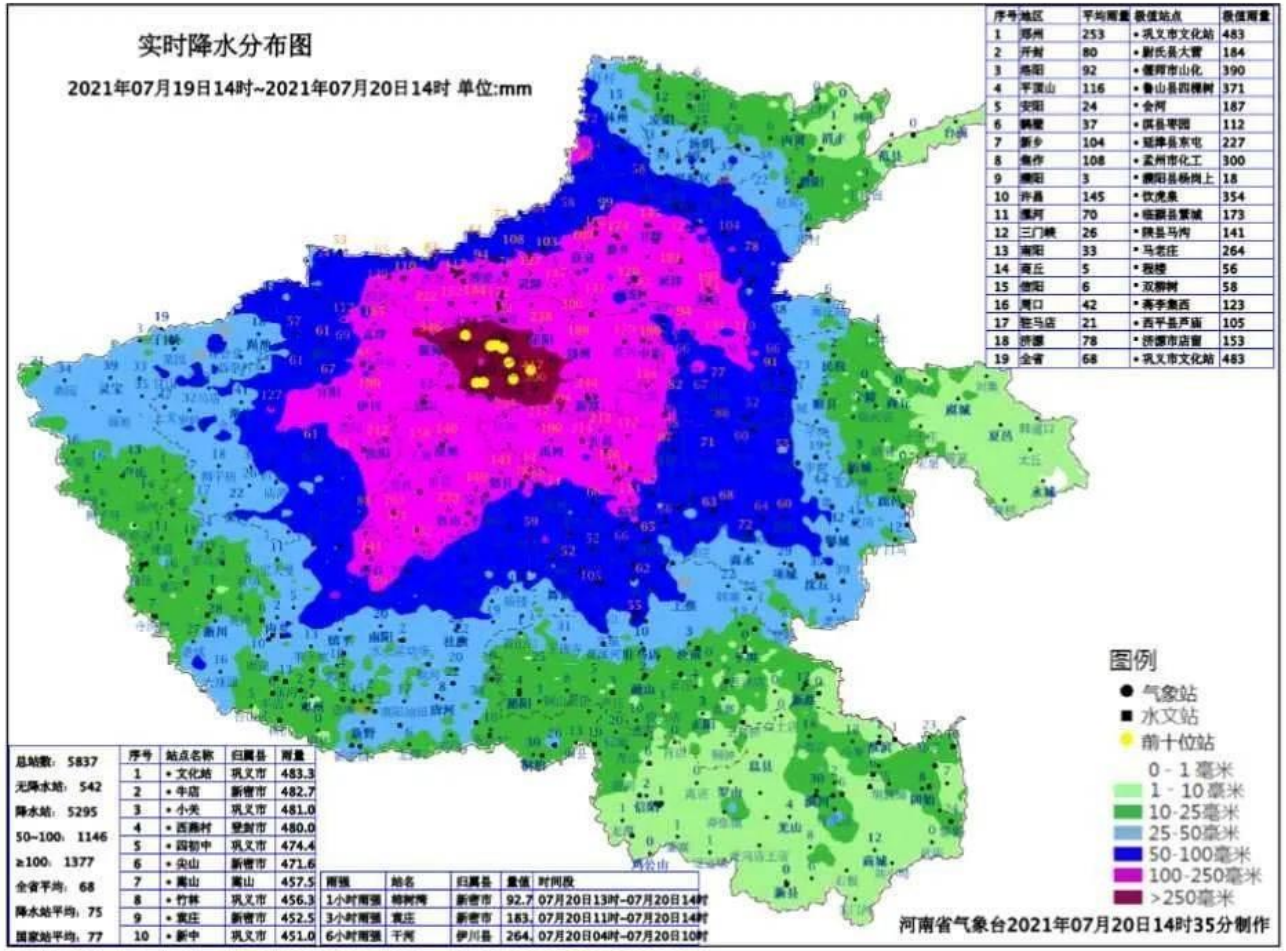


The “21·7” extreme event has a drastic influence on the response surface

Results

- The “21·7” extreme event in Henan Province





https://finance.sina.com.cn/jjxw/2021-07-21/doc-ikqciyzk6680922.shtml

2021 年 7 月 19 日 14 时-20 日 14 时河南省降水量

Results

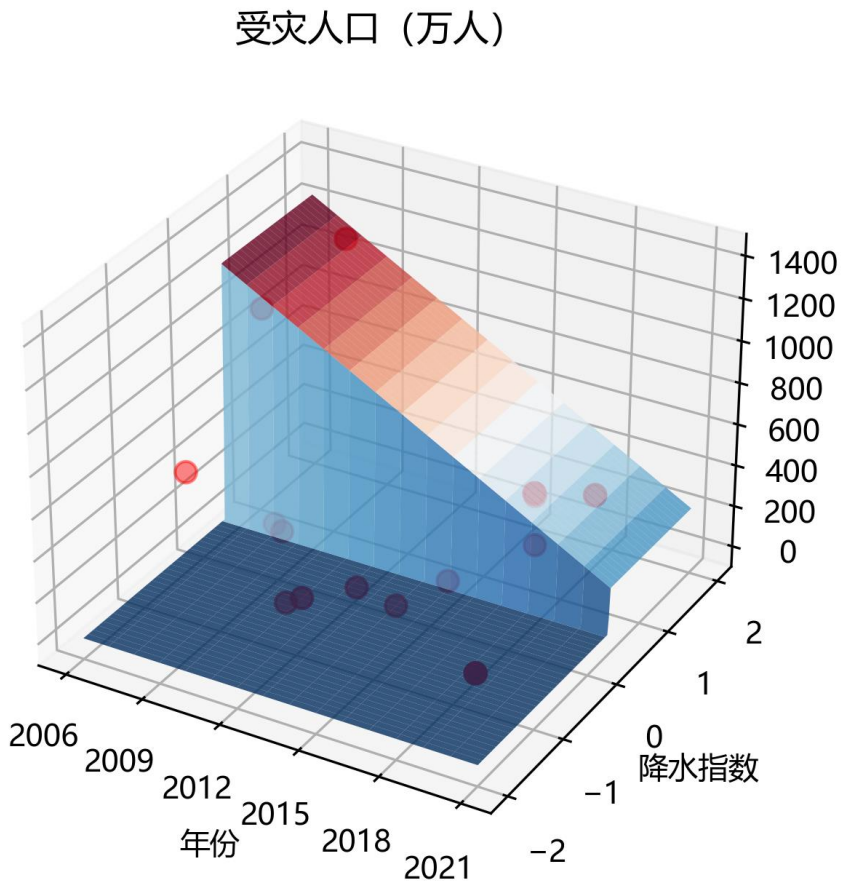
- The “21·7” extreme event in Henan Province

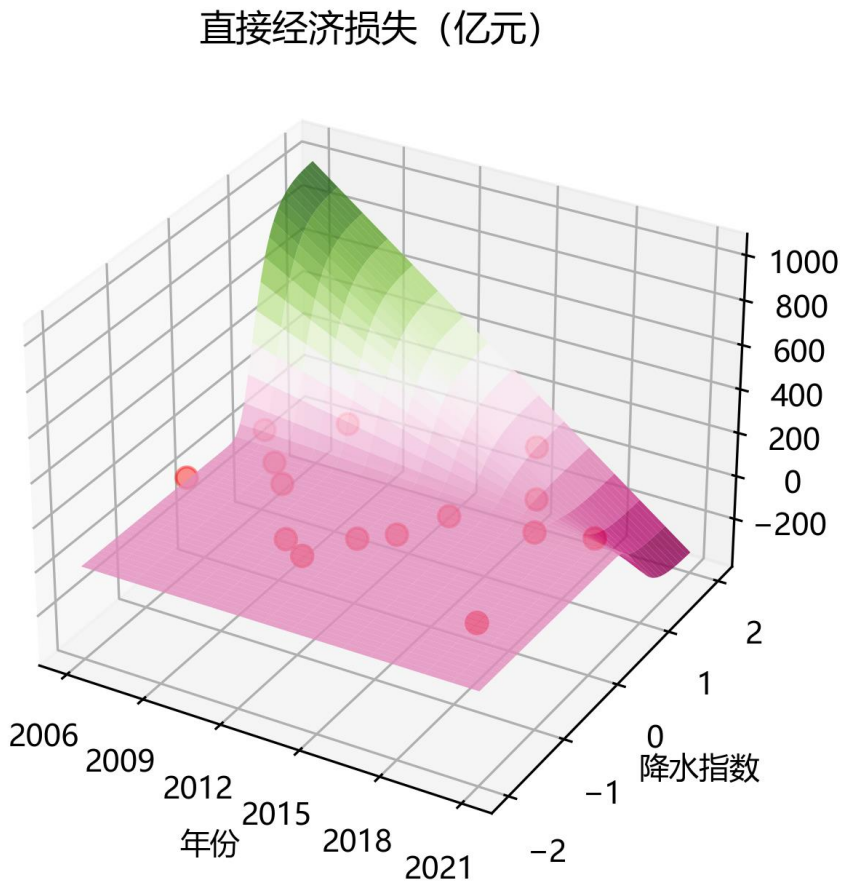
http://www.xinhuanet.com/photo/2021-07/20/c_1127676001_3.htm

https://www.sohu.com/a/478674858_120388781

Results

- Henan Province (2006-2020): 3-D scatter plot and response surface





Without considering the “21·7” extreme event, the response surface is quite different

The implication is not that extreme events can be removed, but that extreme events deserve close attention

Take-home messages

- By mathematically fitting the flood loss function, the three-dimensional scattered points of the flood loss with respect to the flooding risk driver intensity and time can be effectively expanded into a continuous three-dimensional space surface

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- Through this surface, the time can be fixed to evaluate the degree of flood loss under different flooding risk driver intensities, and the intensity of flooding risk driver can be fixed to evaluate the change of flood loss over time

Take-home messages

- By mathematically fitting the flood loss function, the three-dimensional scattered points of the flood loss with respect to the flooding risk driver intensity and time can be effectively expanded into a continuous three-dimensional space surface
- Through this surface, the time can be fixed to evaluate the degree of flood loss under different flooding risk driver intensities, and the intensity of flooding risk driver can be fixed to evaluate the change of flood loss over time
- Extreme events can considerably change the response relationship between flood loss and the intensity and time; correspondingly, in the context of global climate change, the impact of extreme events is particularly worthy of attention

Thank you

Welcome to comments and suggestions