

The Spatio-temporal Pattern of Extreme Temperature Stress and It’s Impact on Rice Yields across Main Rice Planting Areas in China

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Part1

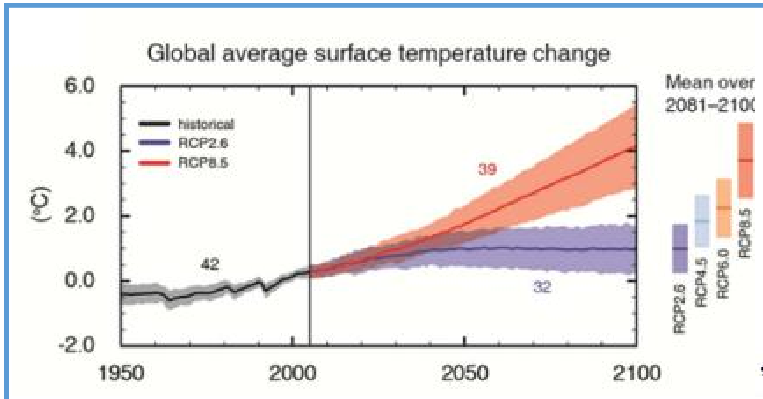
Background

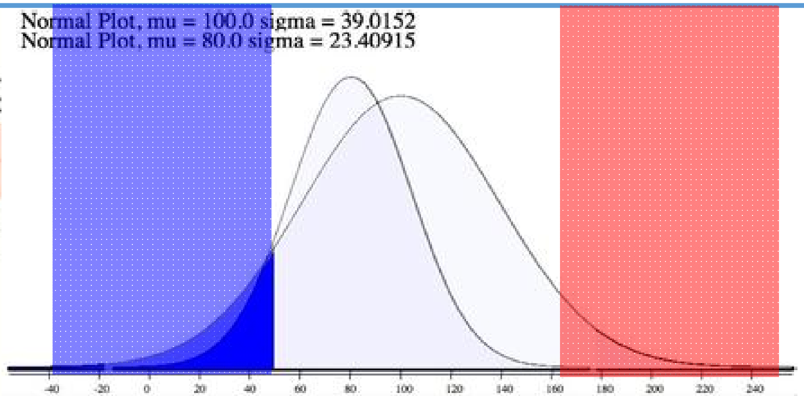
✓ Rice is the most important staple crop and feeds more than half of the world's population;

✓ For example in China, more than 60% people is depended on rice for their daily diet.

Part1

Background





✓ The global mean surface temperature has increased by approximately 0.74 ℃ over the past 100 years (1906–2005), and the regional temperature is projected to increase further by 1.1–6.4 ℃;

✓ In addition, the ongoing climate change could cause the increased frequency and severity of extreme temperature events under the background of global warming.

Part1

Background

ORIGINAL PAPER

Climate trends and crop production in China at county scale, 1980 to 2008

Zhao Zhang · Xiao Song · Fulu Tao · Shuai Zhang ·
Wenjiao Shi

Part1

Background

Climate Trends and Global Crop Production Since 1980

David B. Lobell,[1*] Wolfram Schlenker,[2,3] Justin Costa-Roberts[1]

Part1

Background

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

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

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Agricultural and Forest Meteorology

Responses of wheat growth and yield to climate change in different climate zones of China, 1981–2009

CrossMark

Fulu Tao[a,*], Zhao Zhang[b], Dengpan Xiao[a,c], Shuai Zhang[a], Reimund P. Rötter[d], Wenjiao Shi[a], Yujie Liu[a], Meng Wang[a,c], Fengshan Liu[a,c], He Zhang[a,c]

✓ Many researches focus increasingly on evaluating the impacts of temperature on rice production.

✓ However, some potential bias may have arisen due to the popularly used index of Tmean, which generally removed the marginal yield impacts of the extremes by offsetting higher temperature values with lower ones.

Part1

Background

✓ Therefore, two critical issues, a scientific ETS index and the responses of rice yield to the ETS index, should be focused in order to comprehensively characterize rice exposure to ETS.

✓ The main objectives:

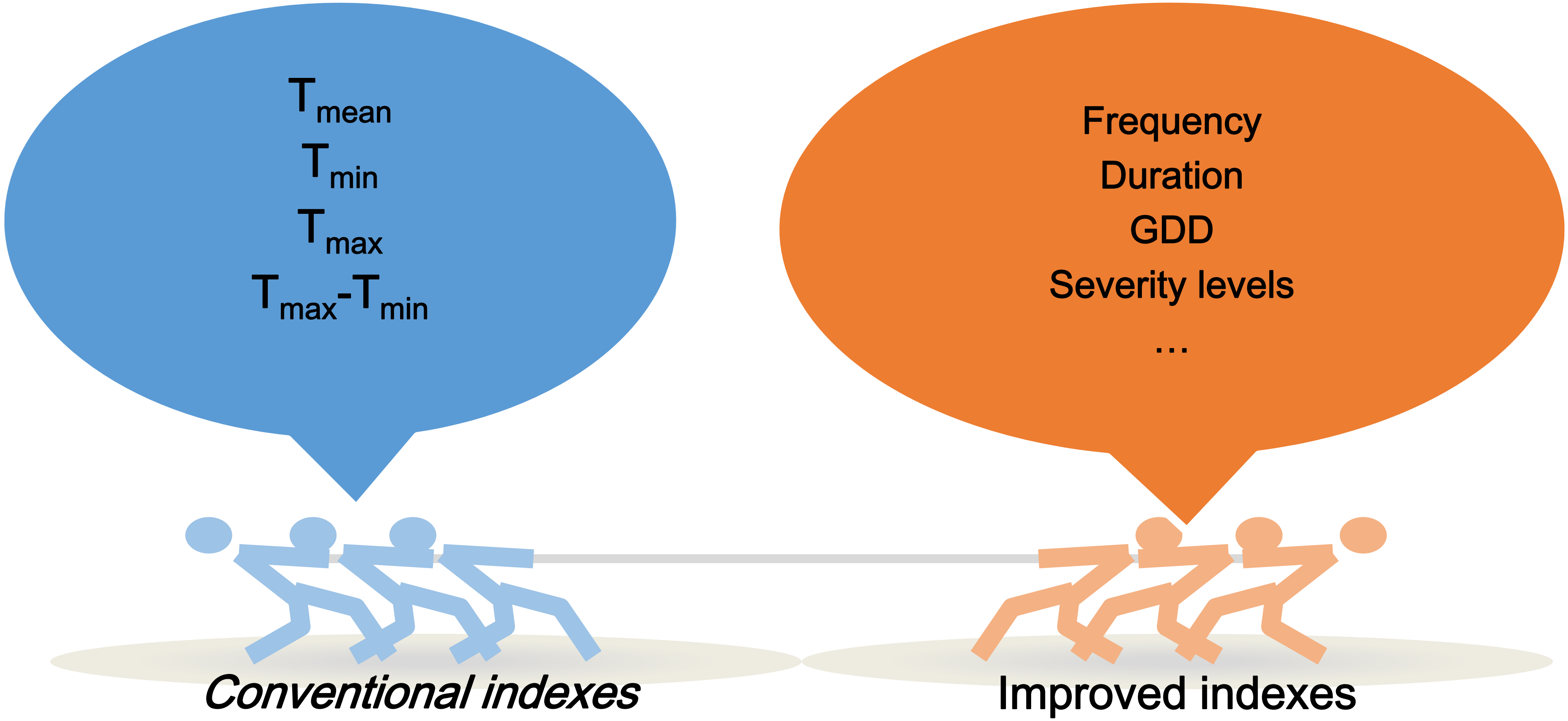
(i) to assess the spatio-temporal patterns of ETS (1960–2009) at county scale in the major rice-planting areas across China;

(ii) to identify particular areas at higher risk of ETS;

(iii) to comprehensively assess the contributions of ETS to county-level rice yields in China (1980–2008).

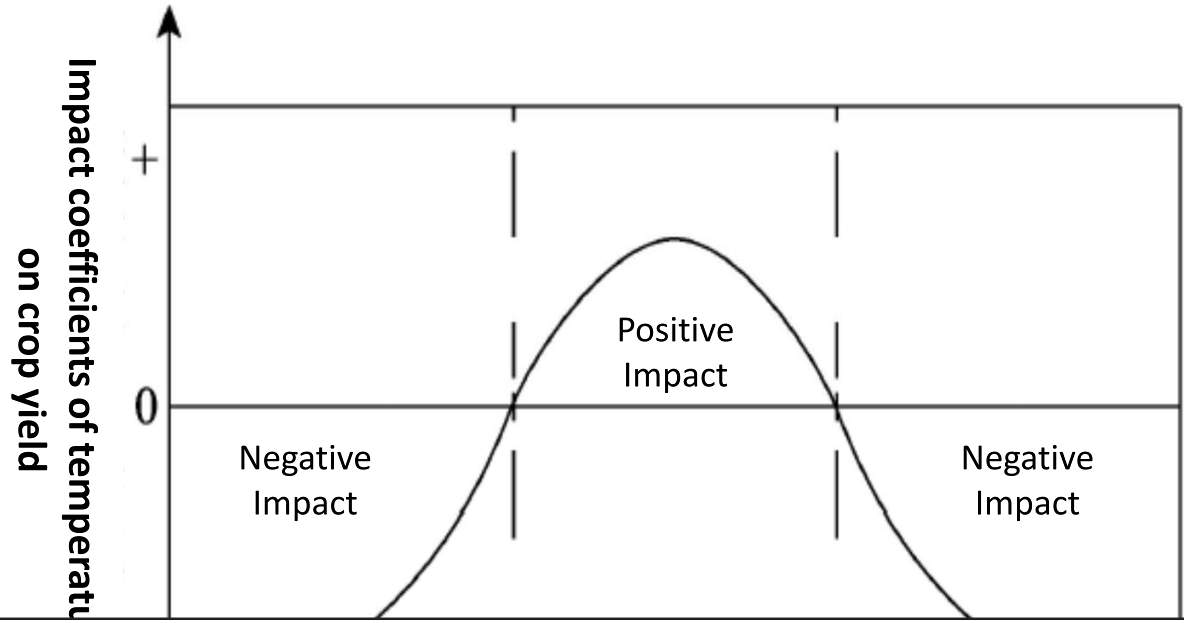
Part2

Methods



Part2

Methods



ETS	Region (rice cultivation)	Booting	Heading-flowering
Cold stress	I (single rice)	≥2 consecutive days with $T_{avg} \leq 17°C$	≥2 consecutive days with $T_{avg} \leq 19°C$
	II & III (single rice)	≥3 consecutive days with $T_{avg} \leq 20°C$	≥3 consecutive days with $T_{avg} \leq 20°C$
	IV (late rice)	≥3 consecutive days with $T_{avg} \leq 20°C$	≥3 consecutive days with $T_{avg} \leq 22°C$
Heat stress	III (single rice) & IV (early rice)	≥3 consecutive days with $T_{avg} \geq 30°C$	≥3 consecutive days with $T_{avg} \geq 30°C$

Table 1. Thresholds of extreme temperature stress in different regions during different stages.

Part2

Methods

$$DD = |T_{base} - T_{avg}| \quad (1)$$

First, calculate daily exposure to extreme temperatures (DD) during each extreme event by ***Eq. (1)***, where Tavg(∘C) is the average of daily minimum temperature (Tmin) and daily maximum temperature (Tmax); Tbase is the threshold of ETS (Table 1). For low-temperature events, if Tavg> Tbase, DD = 0; for high-temperature events, if Tavg< Tbase, DD = 0.

$$GDD = \sum_{j=1}^{N} \sum_{i=1}^{n} DD_{ij} \quad (2)$$

Then, calculate cumulative exposure to extreme temperatures (GDD) during a given stage by ***Eq. (2)***: where N is the frequency of extreme temperature events over a given stage; n is the duration of the jth event; Ddij represents DD on the ith day of the jth event. **$KGDD_{cold}$** means for the cold stress, and **$KGDD_{heat}$** for the heat stress.

Part2

Methods

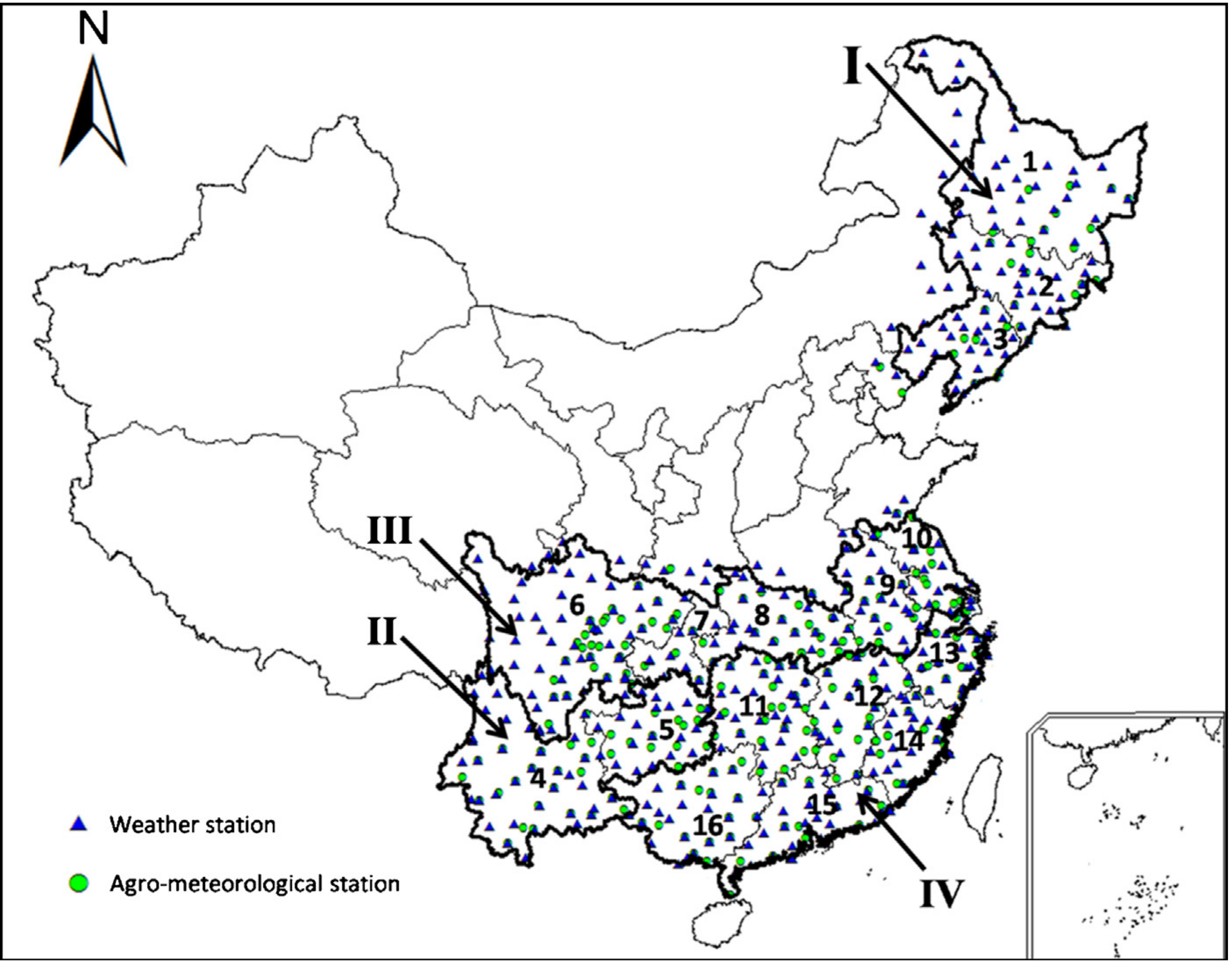
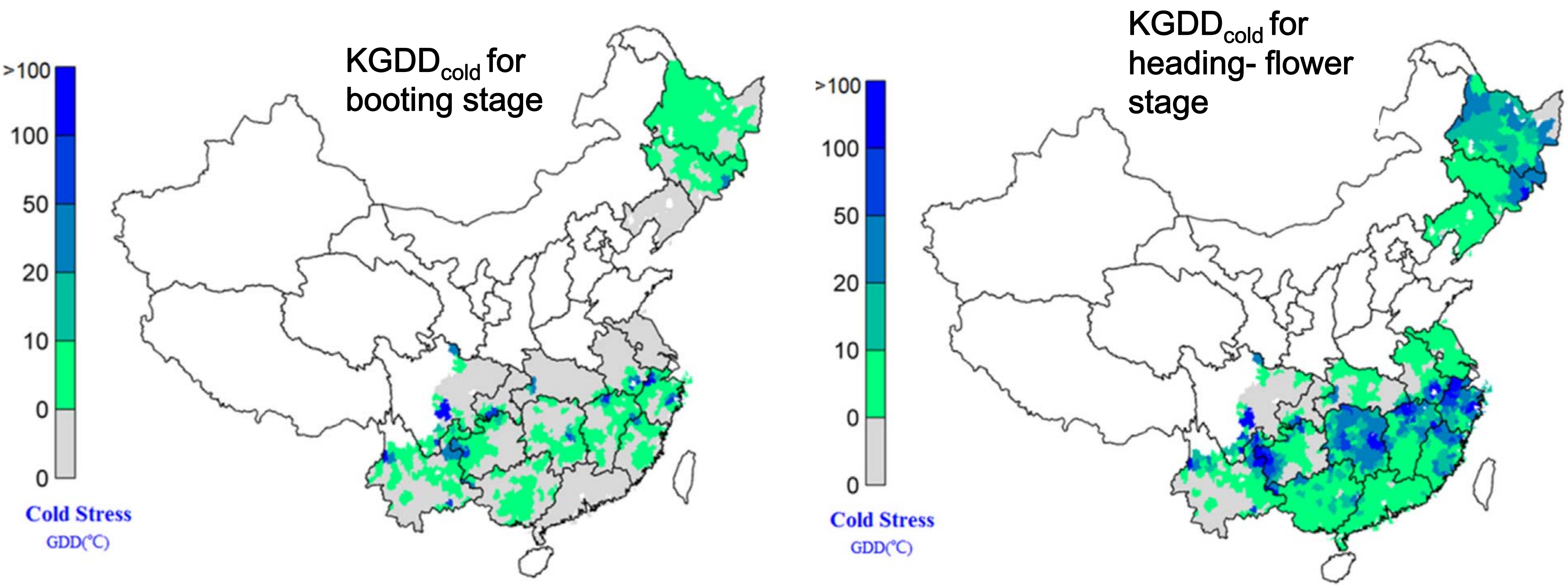


Fig.2 Spatial distribution of rice cultivation in mainland China: (I) single rice in Northeast China; (II) single rice in the Yunnan-Guizhou Plateau; (III) single rice in the Yangtze River basin; (IV) double rice in southern China

Part3

Results

1. Spatial patterns of average annual $KGDD_{cold}$ (◦C)

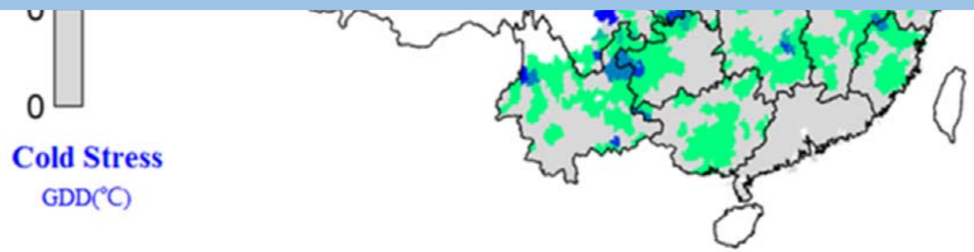


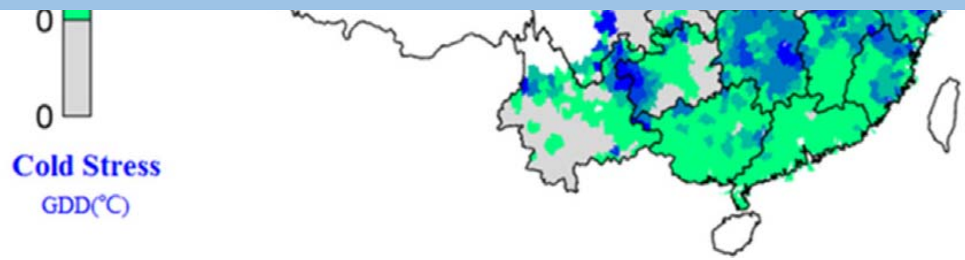
Part3 Results

1. *Spatial patterns of average annual* $KGDD_{cold}$ *(◦C)*

✓ All regions had shown a relative lower exposures to cold stress in booting stage than those of heading-flower stage;

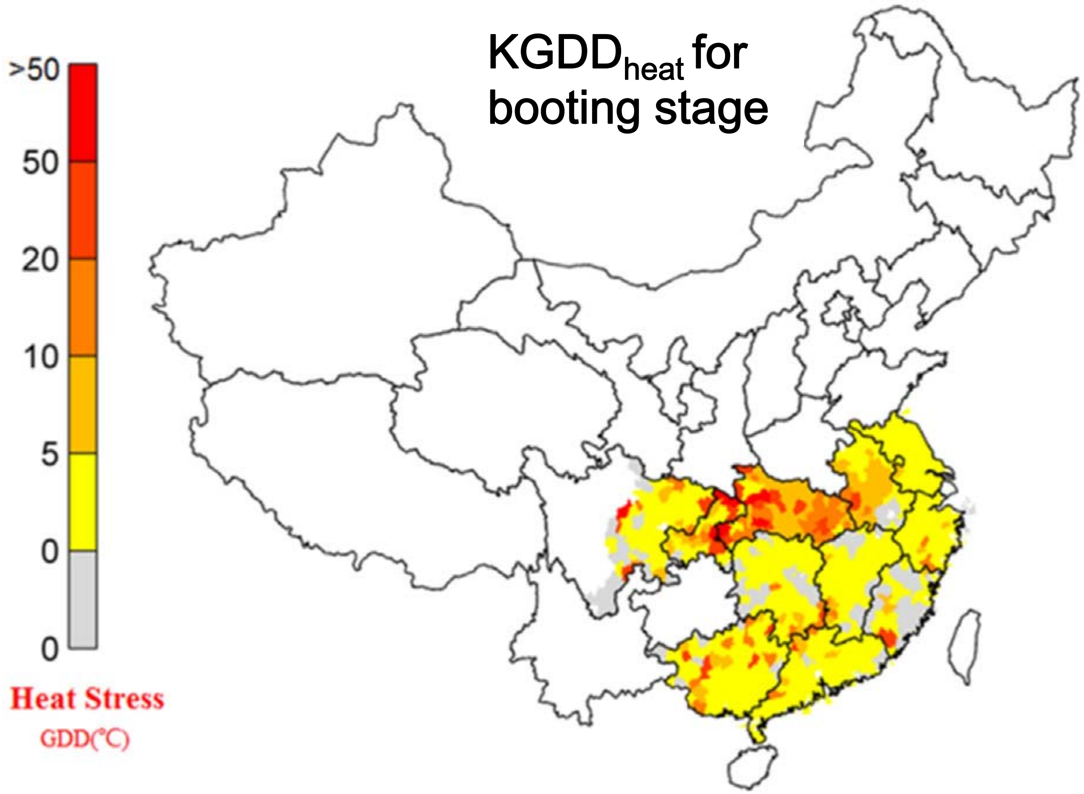
✓ During the heading-flowering stage, region IV was exposed to the most serious cold stress and region III to the slightest, with region I and region II in between.

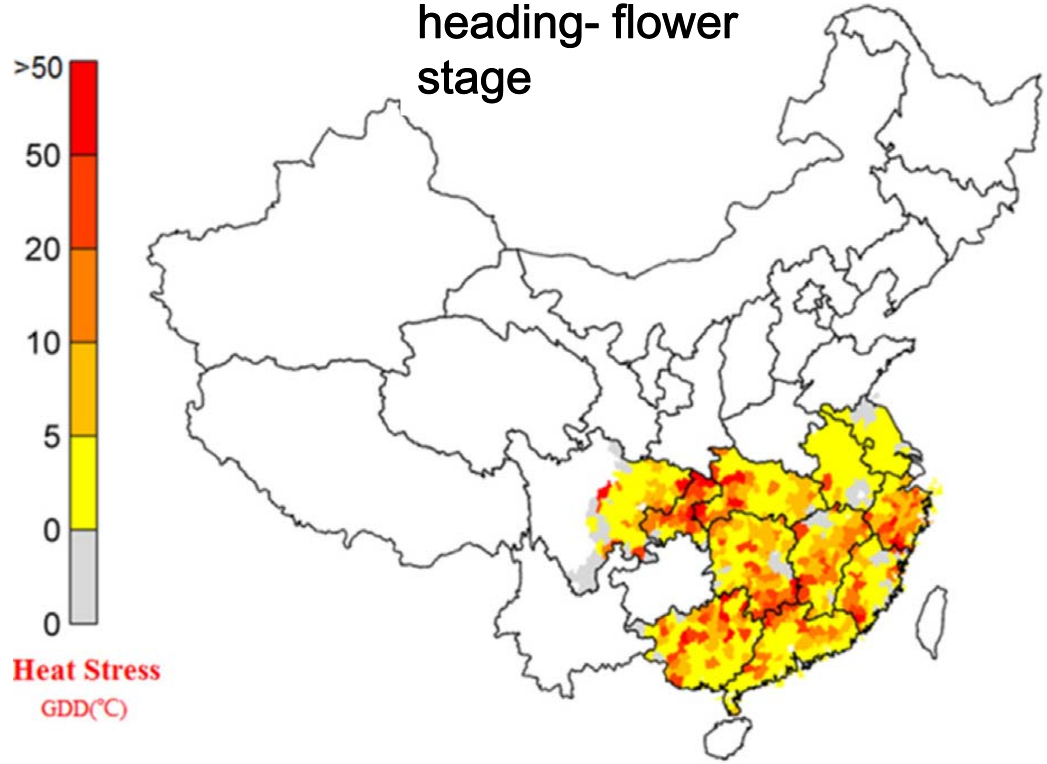




Results

2. Spatial patterns of average annual $KGDD_{heat}$ (°C)





Part3

Results

2. Spatial patterns of average annual $KGDD_{heat}$ (◦C)

- ✓ Across the major planting area, rice exposure to heat stress during the heading-flowering stage was much severer than that during the booting stage ;

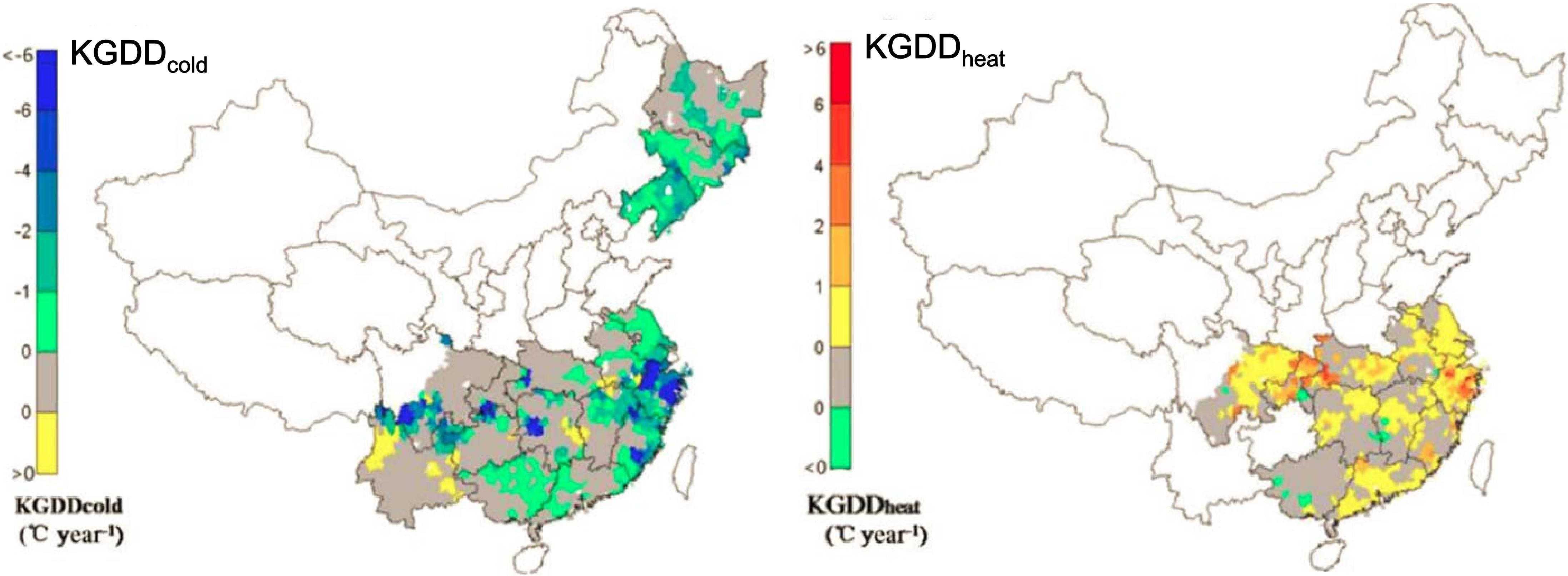
- ✓ Heat stress in Region III was about 7 times higher than that in Region IV during the booting stage ;

- ✓ However, the pattern was reversed during the heading-flowering stage, showing higher exposure to heat stress in Region IV than that in Region III

Part3

Results

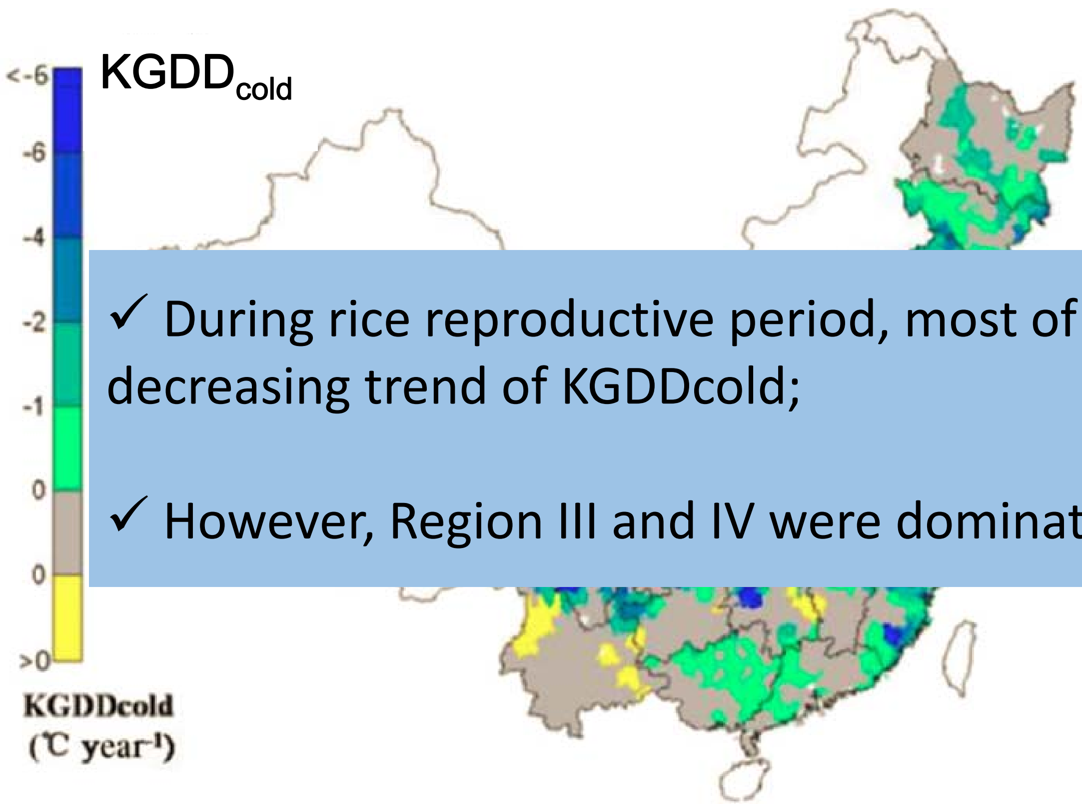
3. Temporal trends of KGDD from 1980 to 2008

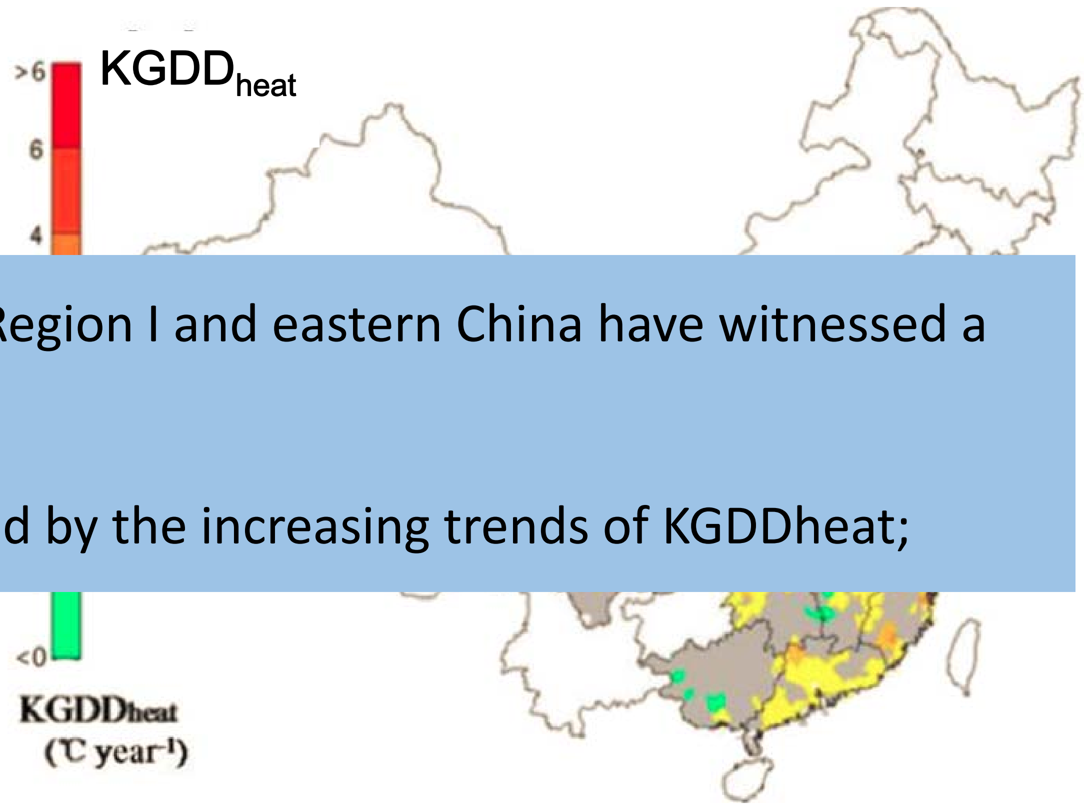


Part3

Results

3. Temporal trends of KGDD from 1980 to 2008



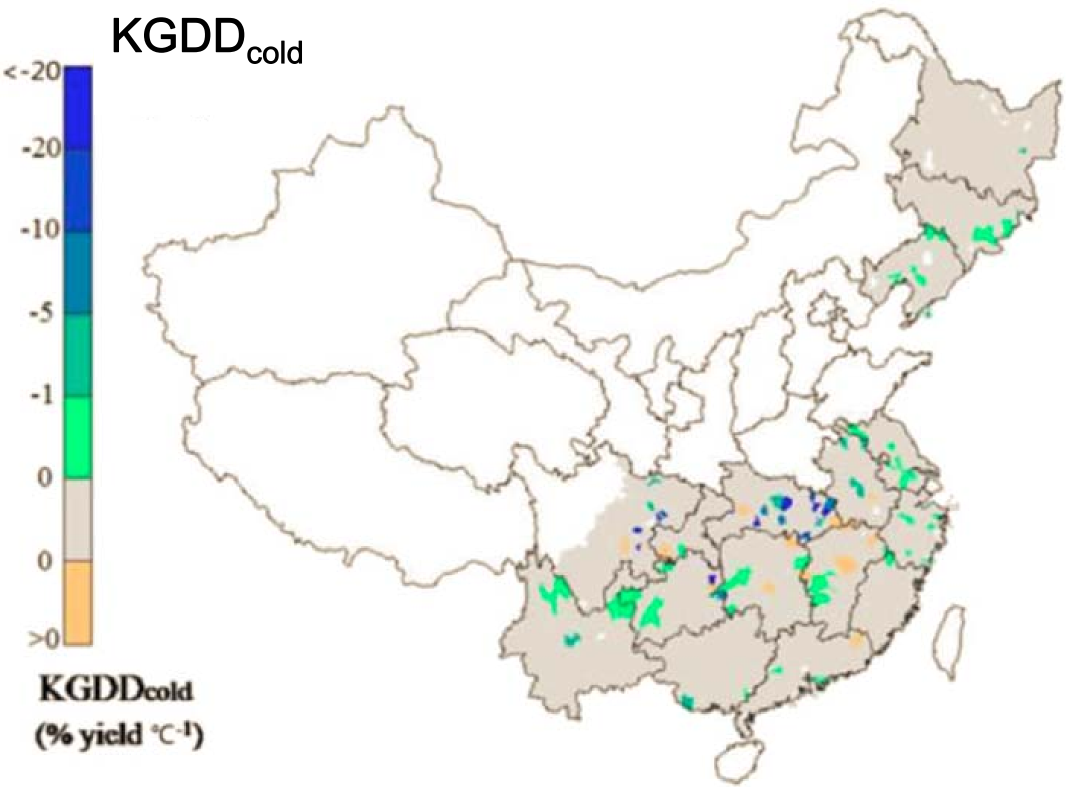


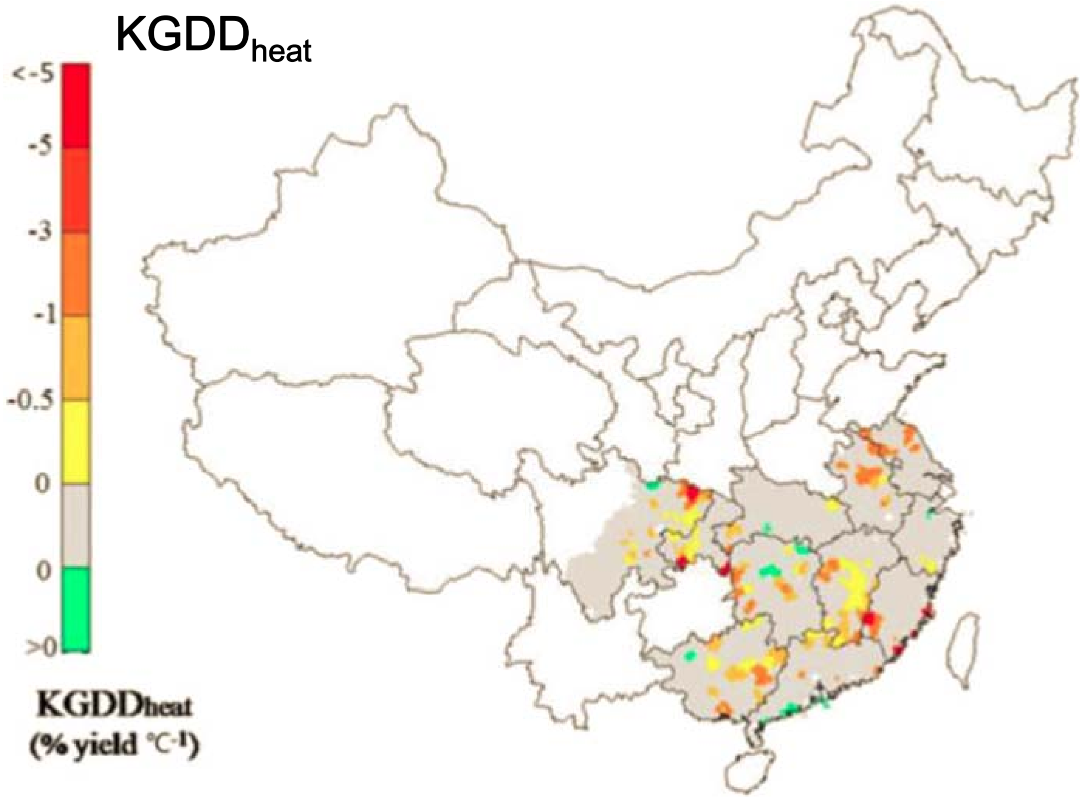
- ✓ During rice reproductive period, most of Region I and eastern China have witnessed a decreasing trend of KGDDcold;
- ✓ However, Region III and IV were dominated by the increasing trends of KGDDheat;

Part3

Results

4. The sensitivities (% yield° C^{-1}) of rice yield to *KGDD*





Part3

Results

4. The sensitivities (% yield° C^{-1}) of rice yield to *KGDD*

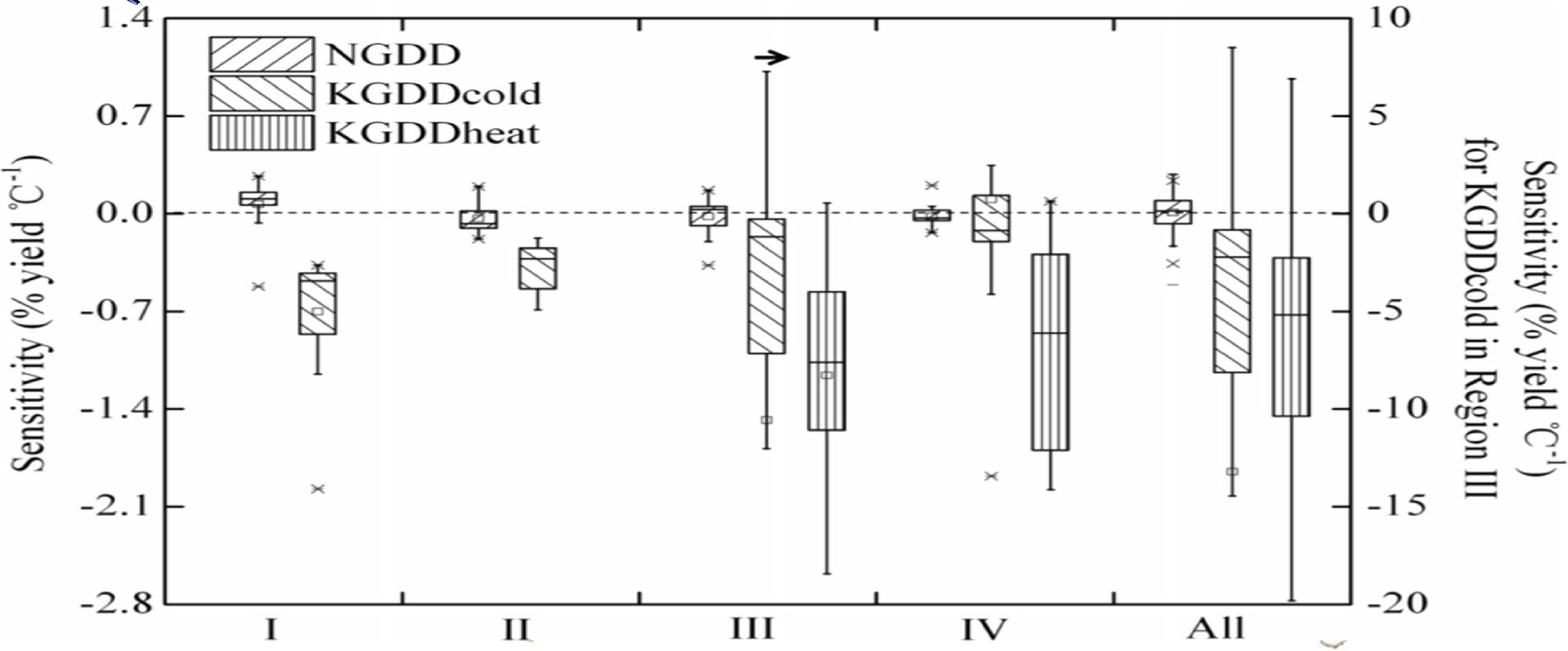
✓ Some portions of Hubei Province had been detected as the most vulnerable areas to cold stress since yield loss would amount to more than −10% with an increase in KGDDcold of each degree;

✓ The areas sensitive to heat stress were mainly distributed in some parts of region iii and iv, where higher stress from KGDDheat would lead to lower yield by 0.5–5 % yield° C^{-1}

Part3

Results

4. *The* sensitivities (% yield° C⁻¹) of rice yield to *KGDD*



Part3

Results

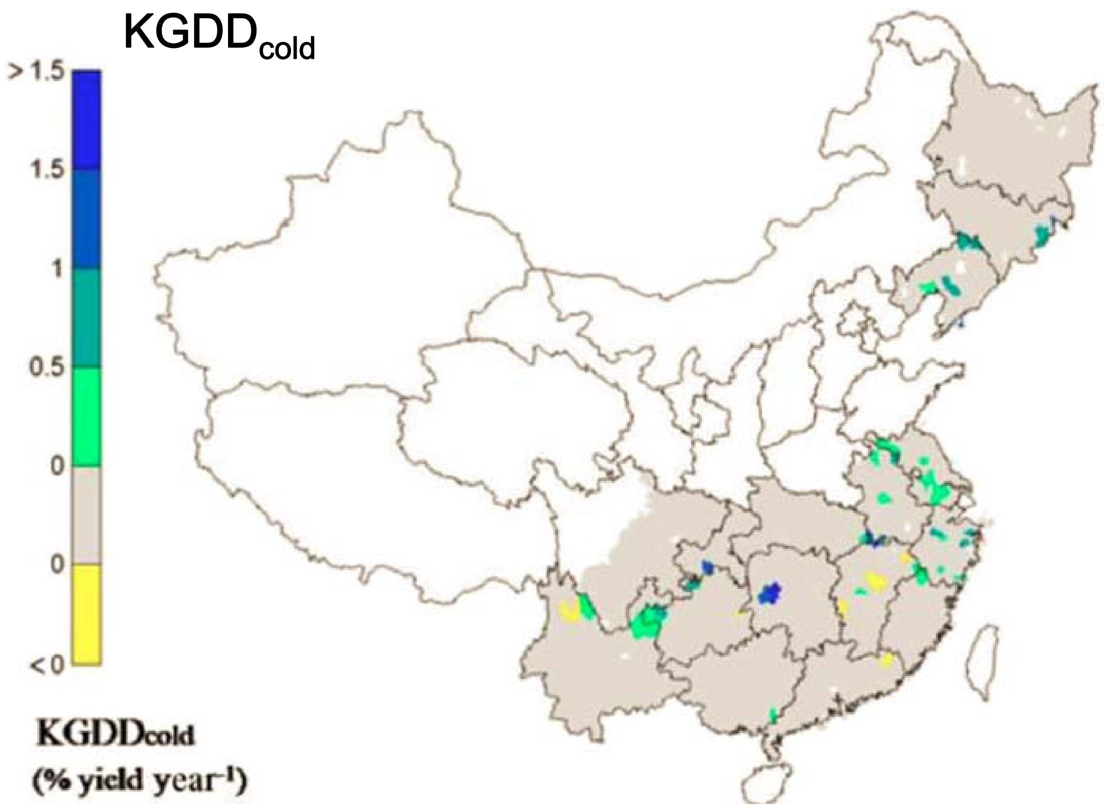
4. The sensitivities (% yield $^{\circ}C^{-1}$) of rice yield to *KGDD*

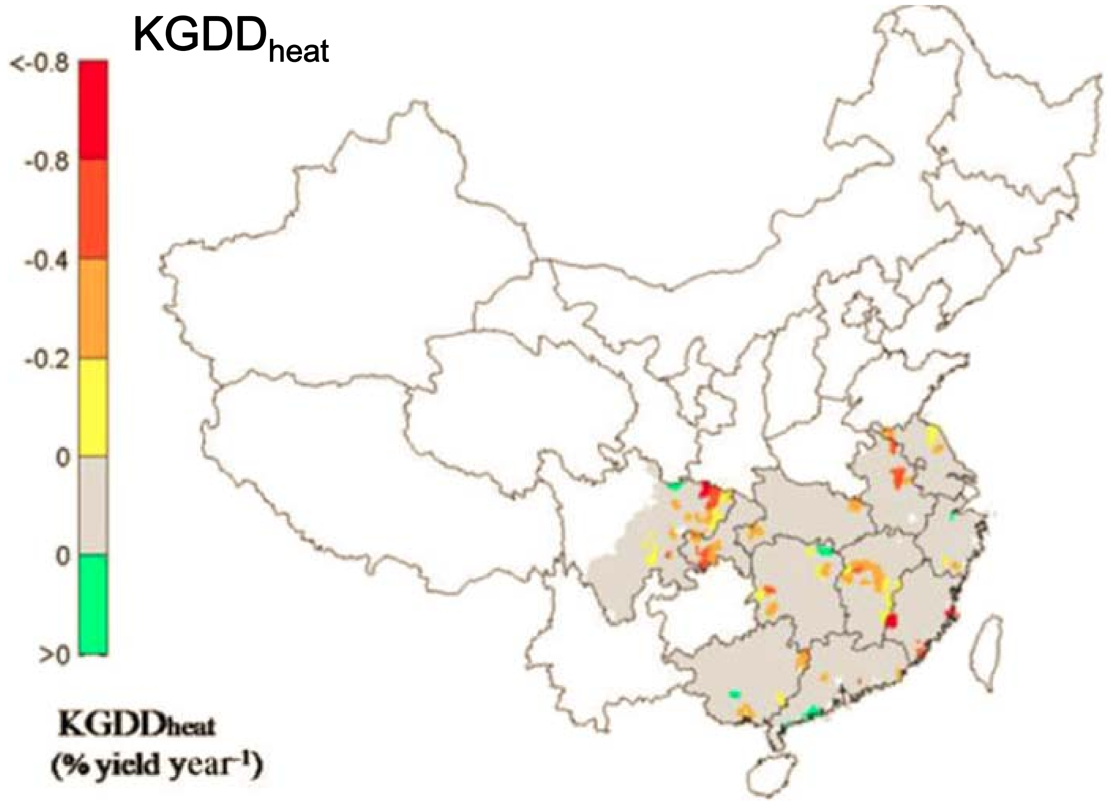
- ✓ Region 1 would suffer from KGDDcold increases (−0.45 % yield $^{\circ}C^{-1}$);
- ✓ Region II would witness a decrease in rice yields KGDDcold (−0.30 % yield $^{\circ}C^{-1}$);
- ✓ Region III responded negatively to KGDD (−1.16 % yield $^{\circ}C^{-1}$ for KGDDcold and −1.04 % yield $^{\circ}C^{-1}$ for KGDDheat);
- ✓ The response patterns in Region IV were −0.14 and −0.84 % yield $^{\circ}C^{-1}$ for KGDDcold and KGDDheat, respectively;
- ✓ Across China, adverse impacts were dominant for KGDD (−0.30 % yield $^{\circ}C^{-1}$ for KGDDcold and −0.71 % yield $^{\circ}C^{-1}$ for KGDDheat

Part3

Results

5. Historical contribution of KGDD to rice yield (1980-2008)





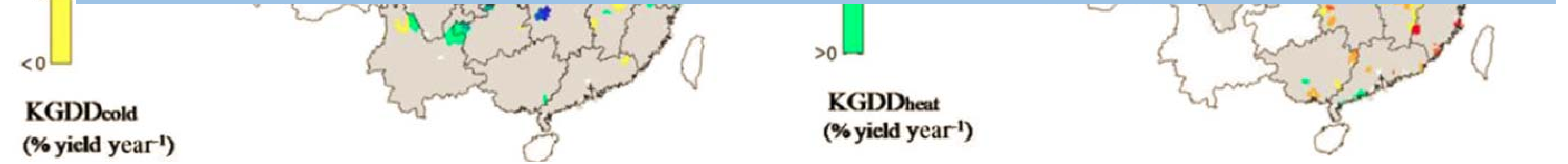
Part3

Results

5. Historical contribution of KGDD to rice yield (1980-2008)

✓ Sporadic portions in Region I, II and eastern China had witnessed an increasing trend of rice yield due to the decreasing KGDDcold. By contrast, rice yield declined by up to 0.9 % per year in some counties of SB due to an increasing trend of KGDDheat.

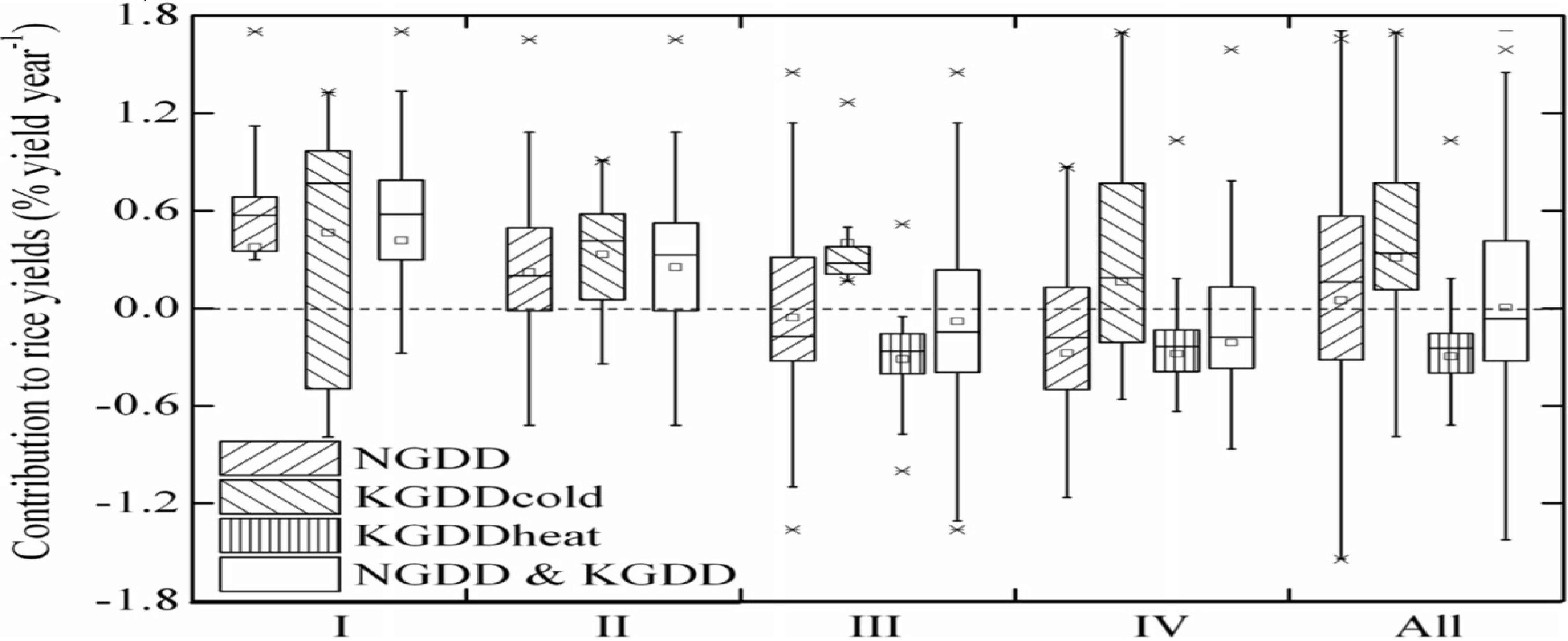
✓ Overall, temperature variations during the past three decades had contributed much to the increased rice yields in the eastern part of Region I (0.5–1.5 % yield year^{-1}) and some portions of Region II and eastern China (0.05–0.5 % yield year^{-1}); but hindered the yield growth in portions of SB and the middle part of Region IV (−0.5 to −0.03 % yield year^{-1}).



Part3

Results

5. Historical contribution of KGDD to rice yield (1980-2008)



Part3

Results

5. Historical contribution of KGDD to rice yield (1980-2008)

✓ In Region I both the trends of NGDD and KGDDcold had contributed much to the improved yields, resulting in an overall contribution of 0.59 % yield year^{-1}

✓ such pattern was also found in Region II, showing 0.21 % yield year^{-1} for NGDD, 0.42 % yield year^{-1} for KGDDcold and 0.34 % yield year^{-1} for overall temperature variations;

✓ In Region III and IV, the trends of KGDDcold had accelerated the yield growth but that of KGDDheat had hampered the increasing trend of rice yield; overall temperature variations imposed negative impacts on rice yields, with −0.14 % yield year^{-1} for Region III and −0.17 % yield year^{-1} for Region IV;

✓Overall temperature variations had contributed positively to rice yields in half of the studied areas (a median of 0.42%yield year^{-1}) and negatively in the other half (a median of −0.31 % yield year^{-1}), resulting in an average of 0.01 % yield year^{-1}

Part4

Conclusions

C1

- Global warming over 1960–2009 did increase heat stress ((**0.04** and **0.12∘C year^{-1}** for the stages of booting and heading-flowering, respectively) and reduce cold stress (**−0.03** and **−0.21∘C year^{-1}**) in the major rice-planting areas across China;

C2

- Historical temperature variations (NGDD and KGDD) had measurable impacts on rice yields with a distinct spatial pattern;

C3

- Such variations had contributed much to the increased rice yields in Northeast China Region I) (**0.59 %**) and some portions of the Yunnan-Guizhou Plateau (Region II) (**0.34 %** yield year^{-1});

C4

- However, they had seriously hindered the improvements of rice yields in the Sichuan Basin (**−0.29 %**) and the southern cultivation areas (Region IV) (**−0.17 %** yield year^{-1}).

THANK YOU FOR ATTENTIONS

ANY COMMENTS, PLEASE!