Impact of climate change on heating and cooling degree days and potential energy demand in the household sector of China

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Applications of RegCM:

- ✓ Climate change simulations (Gao et al., 2001, 2002, 2008, 2010, 2012)
- ✓ The role of model resolution in East Asia (Gao et al., 2006)
- ✓ Landuse effects on climate over China (Gao et al., 2003, 2007)
- ✓ Modeling of dust events (Zhang et al., 2009)
- ✓ Modeling of aerosols and their climate effects (Ji et al., 2010)
- ✓ Construction of gridded observation dataset over China (Xu et al., 2009; Wu et al, 2013)
- ✓ Other domains (Mediterranean, Gao et al., 2006, 2007; Australia, Song et al., 2009)
- ✓ Model development and tuning: Southeast Asia
- ✓ Data provided for impact studies
- ✓ Impact studies: changes in HDD and CDD

Motivation:

How the possible future energy demand in the household sector of China may change under the global warming?

- **The warming lead to less heating demand**
- **The warming lead to more cooling demand**
- **Balance?**

Outline

- Data and methods
- Validation of the climate model
- Future changes
- Conclusion and discussions

1. Data and methods

- **Observational dataset: CN05.1 (Wu and Gao, 2013)**

- **Model data (Gao et al., 2013):**
  - ✓ **Climate change simulations conducted by the ICTP (International Centre for Theoretical Physics) RegCM4**
  - ✓ **Resolution: 50 km×50 km**
  - ✓ **Reference simulation (1951-2005)**
  - ✓ **Future simulation (2006-2099)**
  - ✓ **Scenarios: RCP4.5, RCP8.5**

- **Population data:**

  The $0.5^{o}\times0.5^{o}$ (longitude-latitude) gridded dataset developed by the International Institute for Applied System Analysis (IIASA, 2007).

- **Periods: 1986-2005 for present day**

  2046-2065 for mid-21st century

  2080-2099 for the end of 21st century

- **Focus: changes of mid 21st century under RCP4.5 and end of 21st century under RCP8.5**

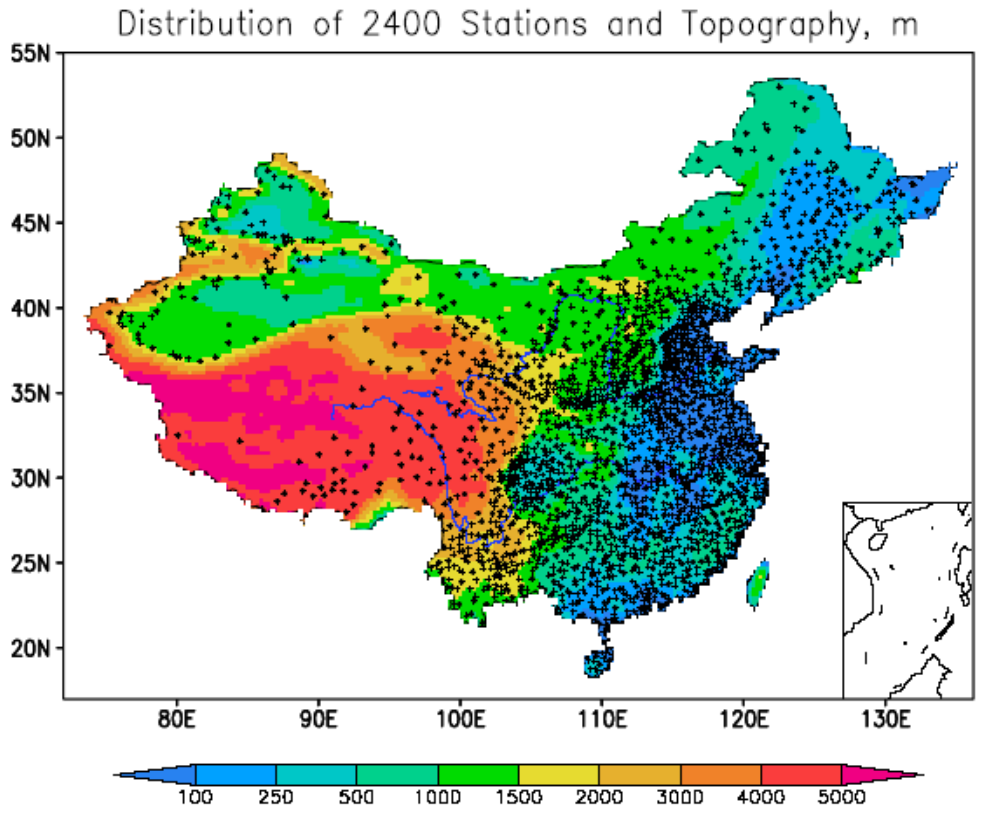
CN05.1: daily temperature (mean, max, min), precipitation

Method: “anomaly approach” as CRU and CN05 data

Mean: 1971–2000, by thin-plate smoothing splines (ANUSPLIN)

Anomaly: 1961–2005, by angular distance weighting (ADW)

Station numbers: 2416



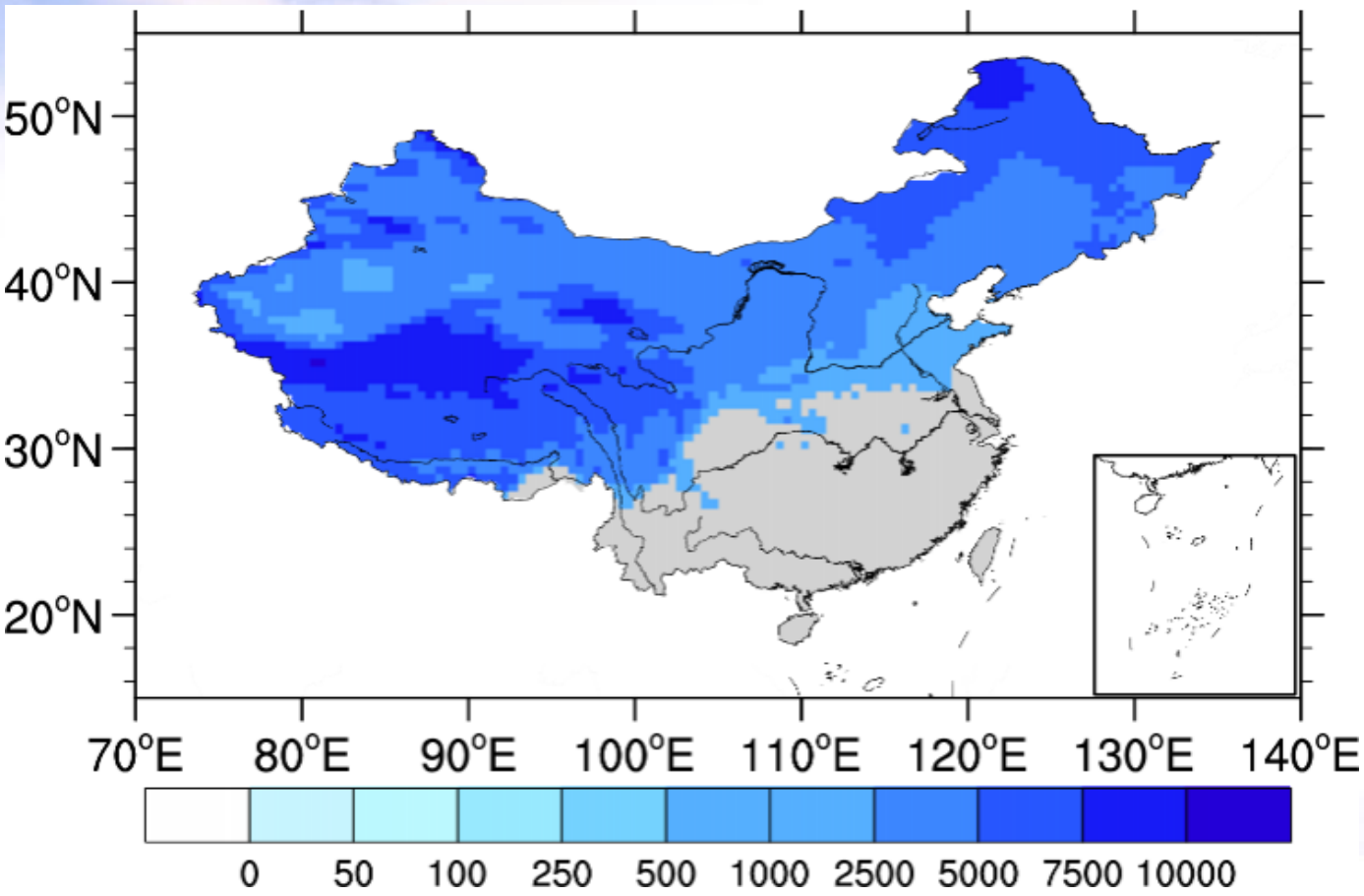
- **Degree days:**

$$\begin{cases} HDD = \sum_{i=1}^{n} rd(T_{b1} - T_i) \ \ (\text{if DEH} - \text{DSH} > 90) \\ CDD = \sum_{i=1}^{n} rd(T_i - T_{b2}) \end{cases}$$

n: number days in the year (365 or 366)

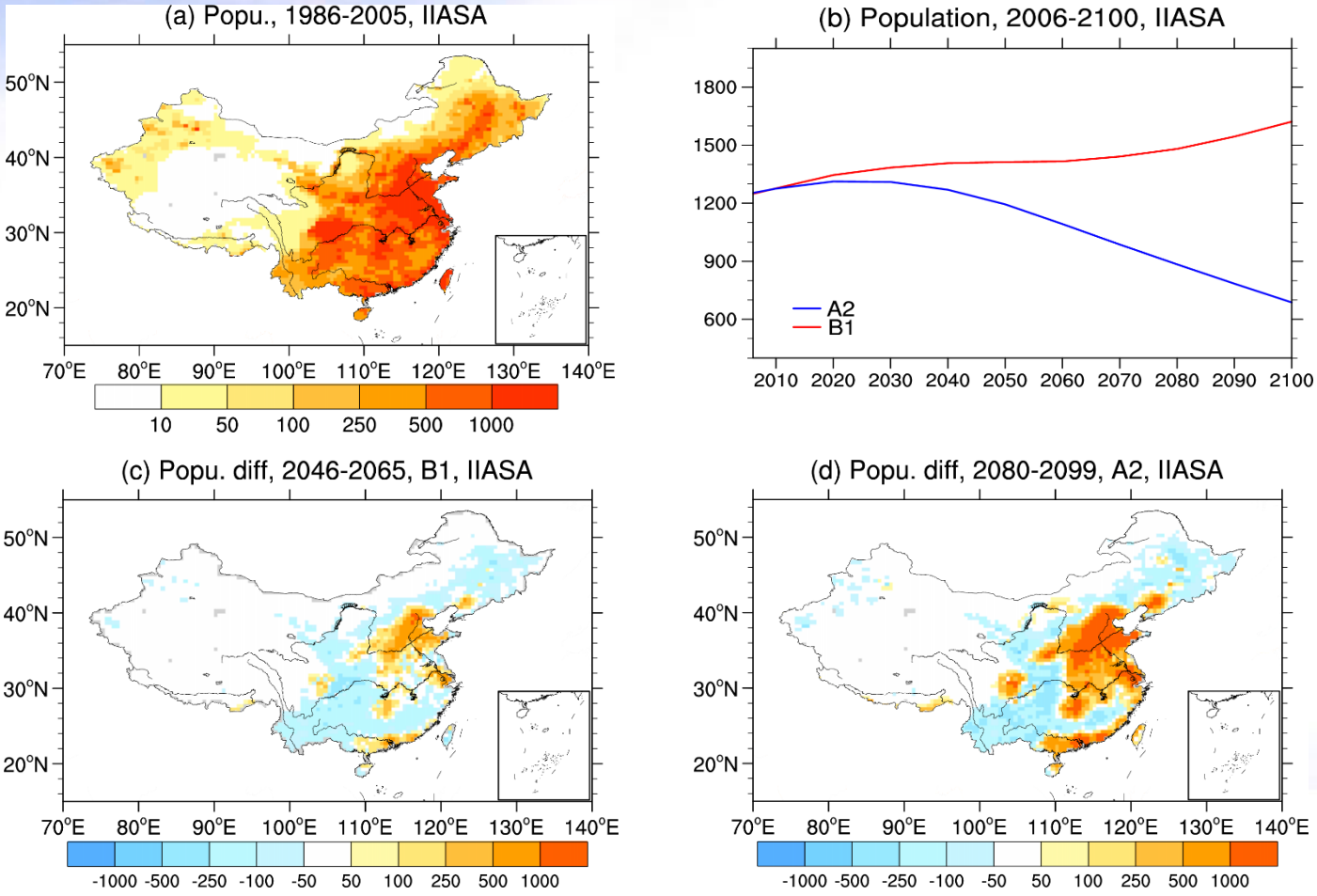
rd: equal to 1 if Ti >Tb1 or <Tb2, or else equal to 0.

- **The policy for heating days :**
  - ✓ **only areas with more than 90 days of temperature < 5ºC can be heated (to 18ºC), Tb1;**
  - ✓ **the heating starts/ends when the temperature is lower / greater than 5ºC for a continuous 5 day period in an annual cycle, Tb2.**
- **The cooling days occur when the out-door air temperature exceeds 26ºC (to the reference value of 26ºC)**
- **Provide also the sensitivity of more commonly used reference temperatures to 18ºC/22ºC**



Areas with central heating in China following the present day policy (blue)

➢ Weighting by population

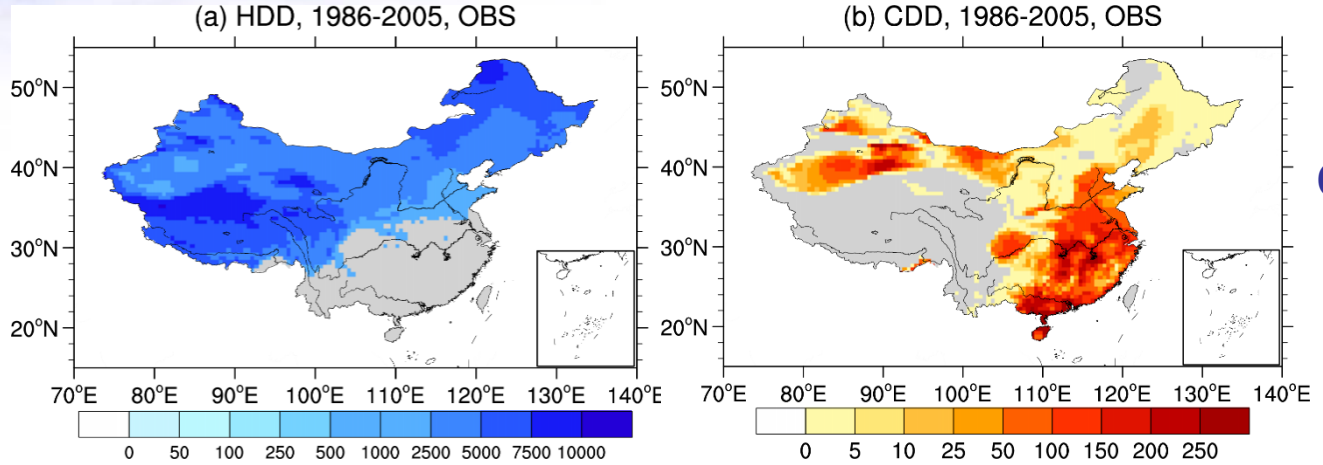


Population density in China. Units are thousands per 0.5º×0.5º grid in (a), (c), (d) and million in (b).

2. Validation of the climate model

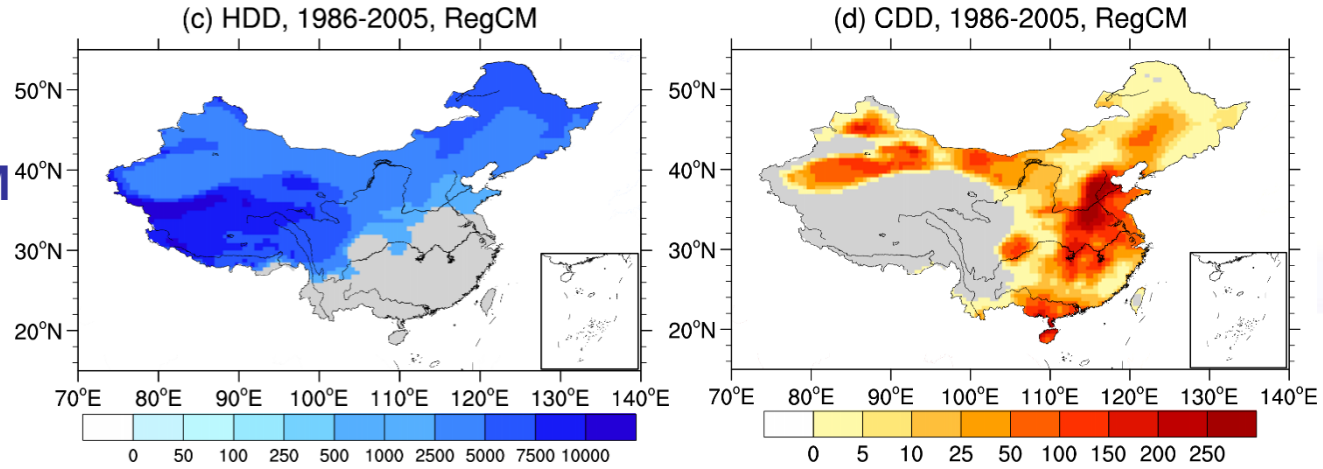
HDD **CDD**

OBS



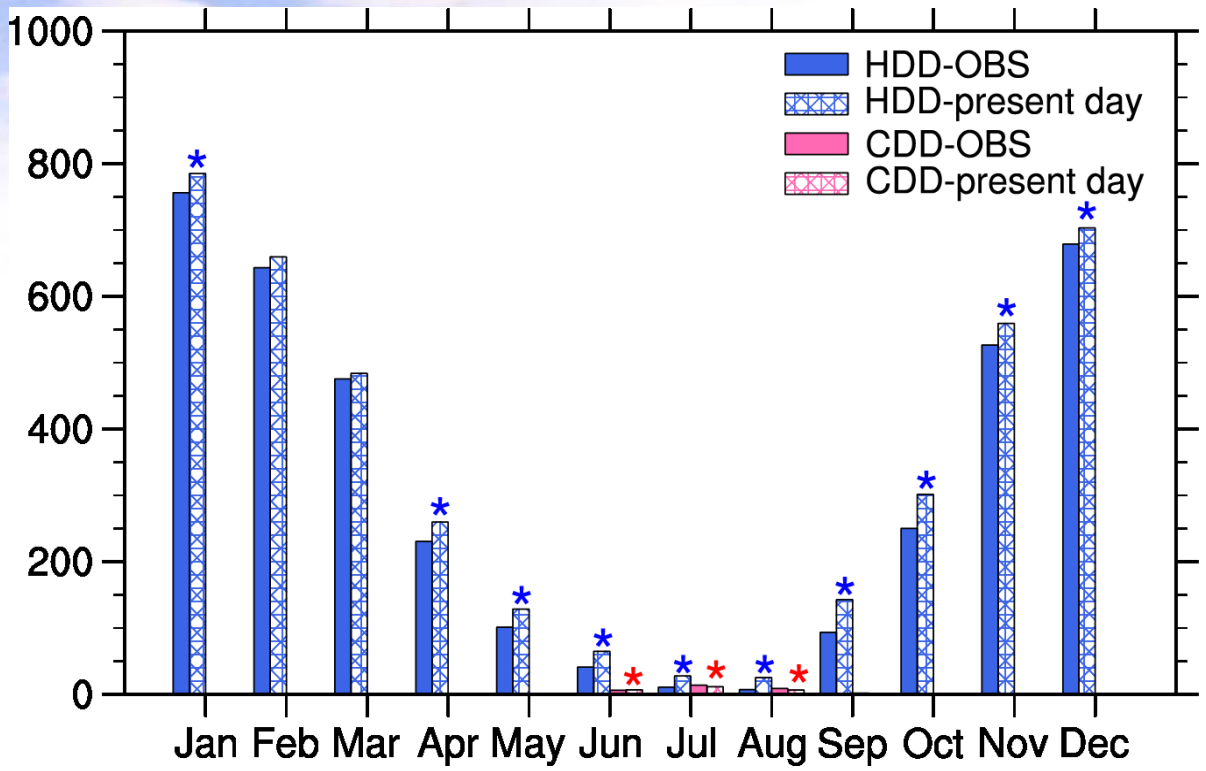
OBS

RegCM



RegCM

HDD and CDD in the present day (1986-2005) (unit: $^{o}C \cdot d$)

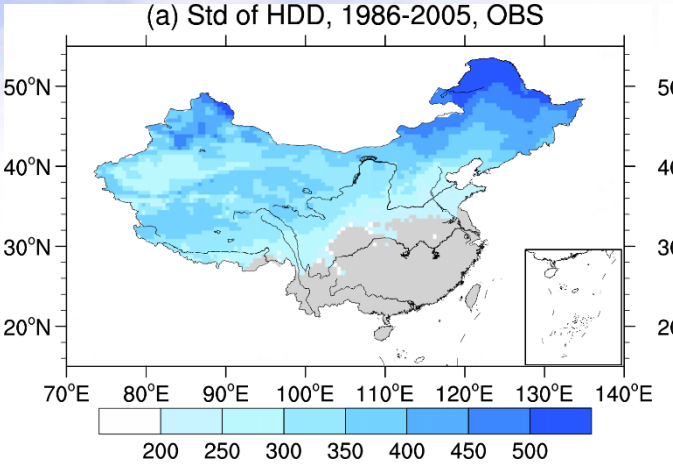


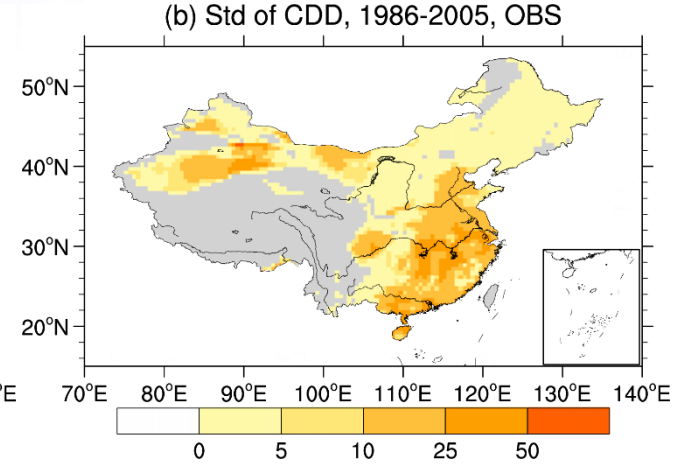
Annual cycle of the China-mean HDD and CDD in the present day (1986-2005) (unit: $^{o}C \cdot d$)

HDD

CDD

OBS





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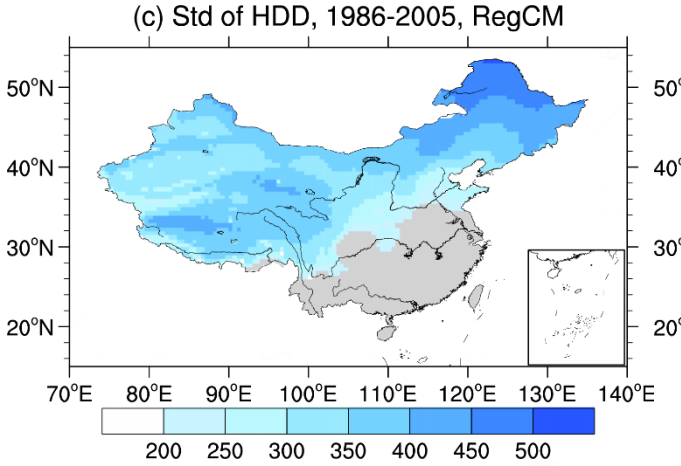
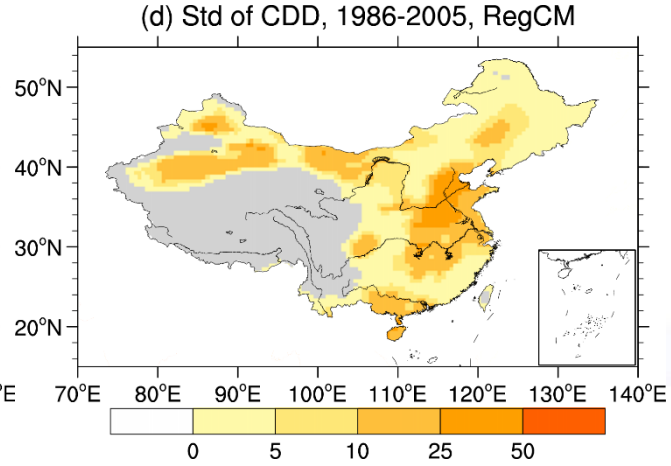
RegCM





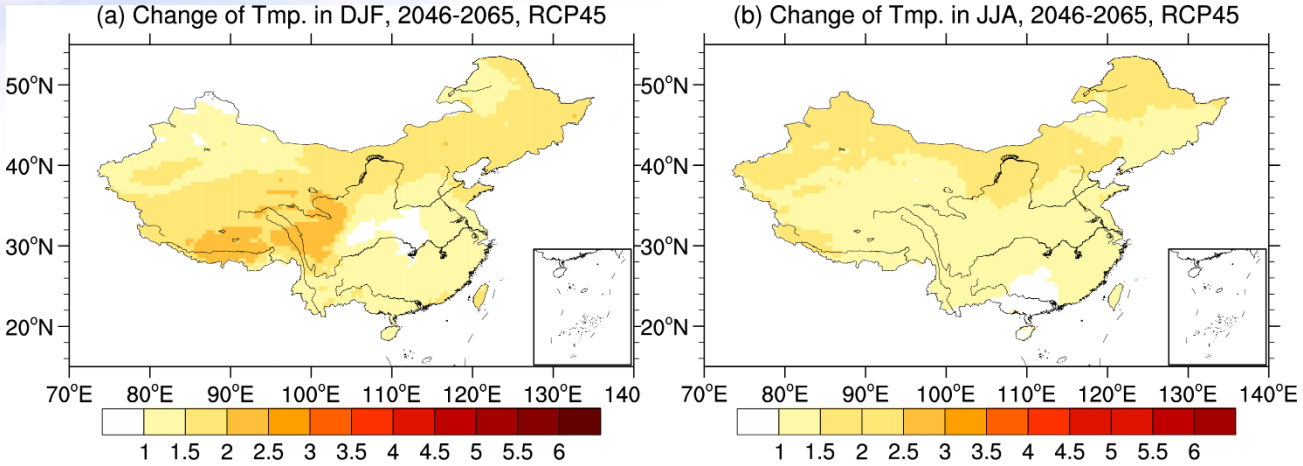
RegCM

Interannual variability as measured by the interannual standard deviation for the present day period 1986-2005 (unit: ^{o}C·d)

3. Future changes

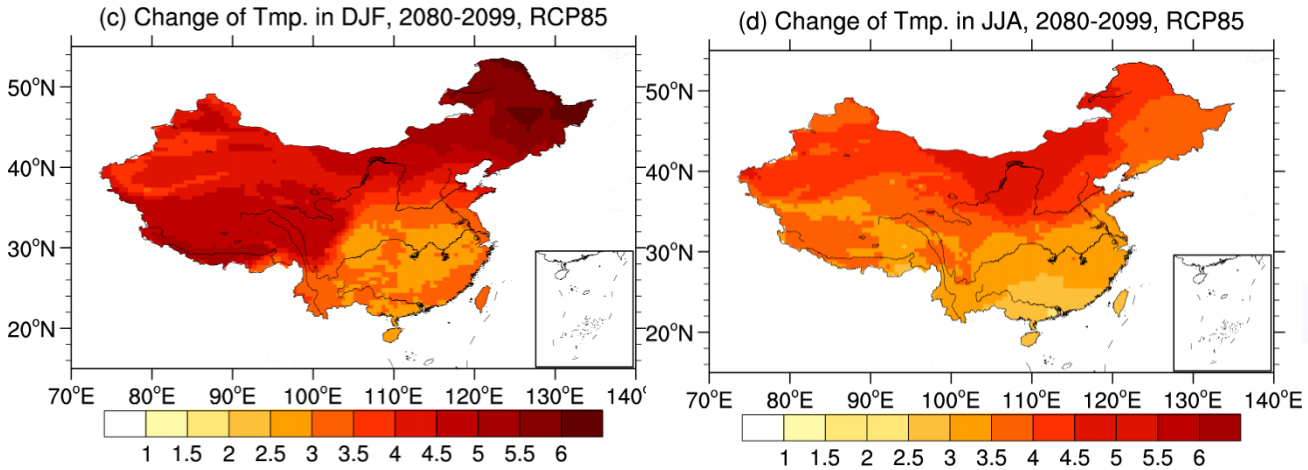
DJF **JJA**

RCP4.5



RCP4.5

RCP8.5

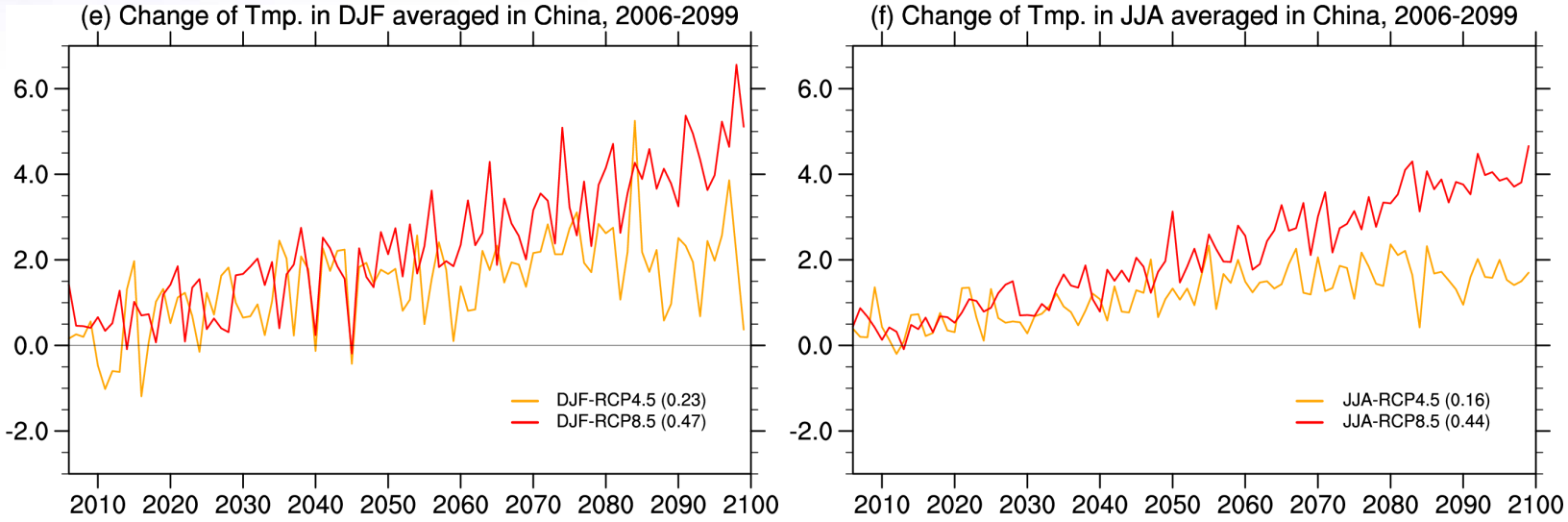


RCP8.5

Temperature changes over China relative to 1986-2005 (unit: ^{o}C)

DJF

JJA

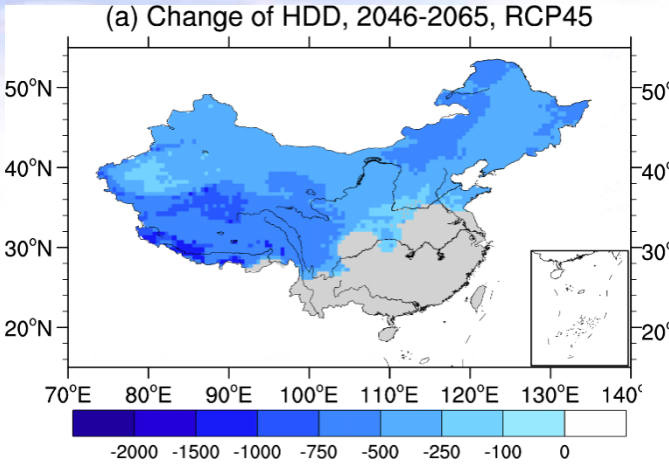


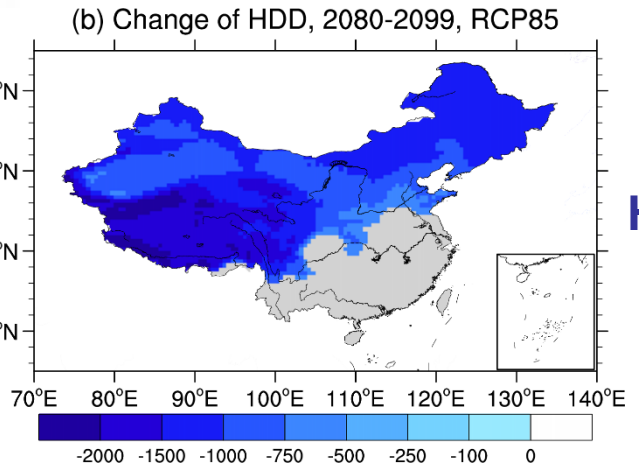
Regional mean temperature changes over China in the 21st century (unit: ^{o}C)

RCP4.5

RCP8.5

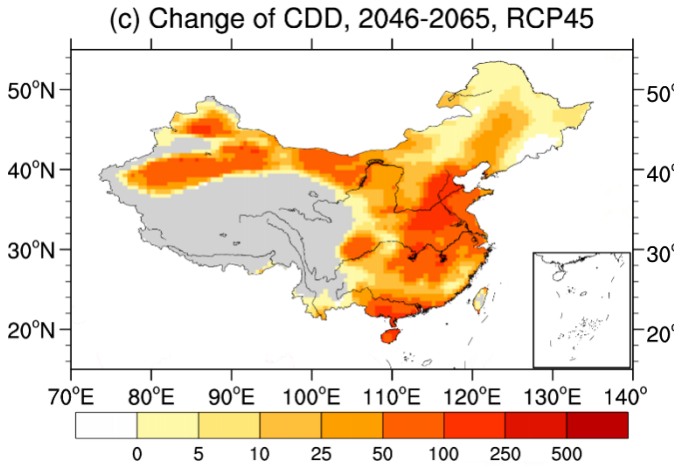
HDD

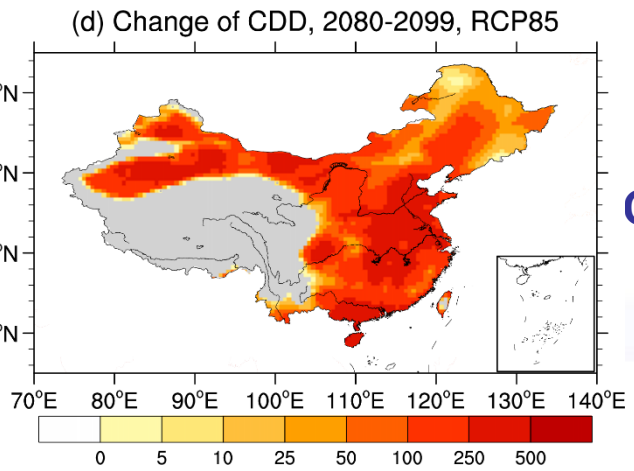




HDD

CDD





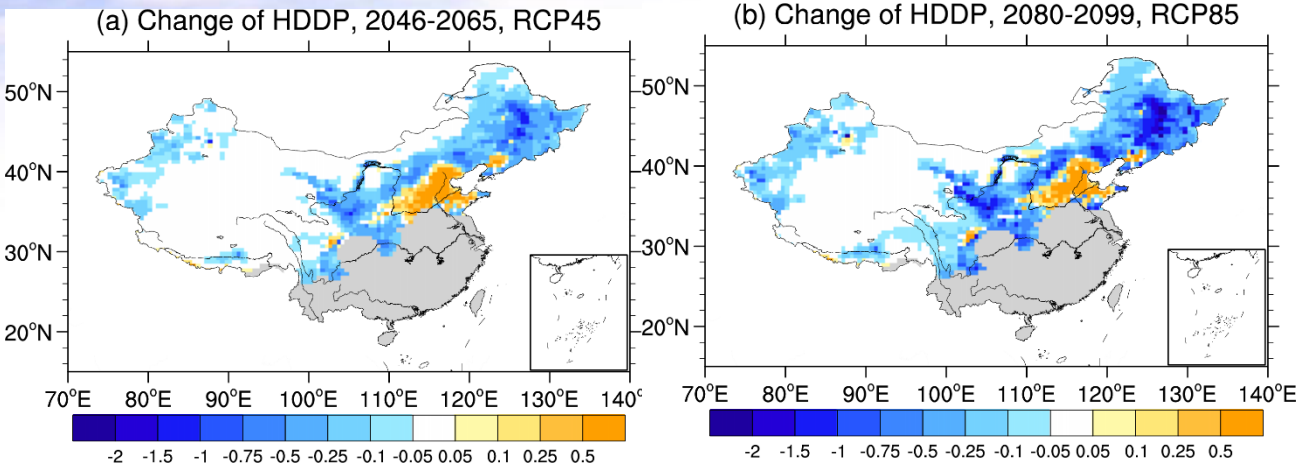
CDD

Changes of HDD and CDD over China (unit: ºC·d)

RCP4.5

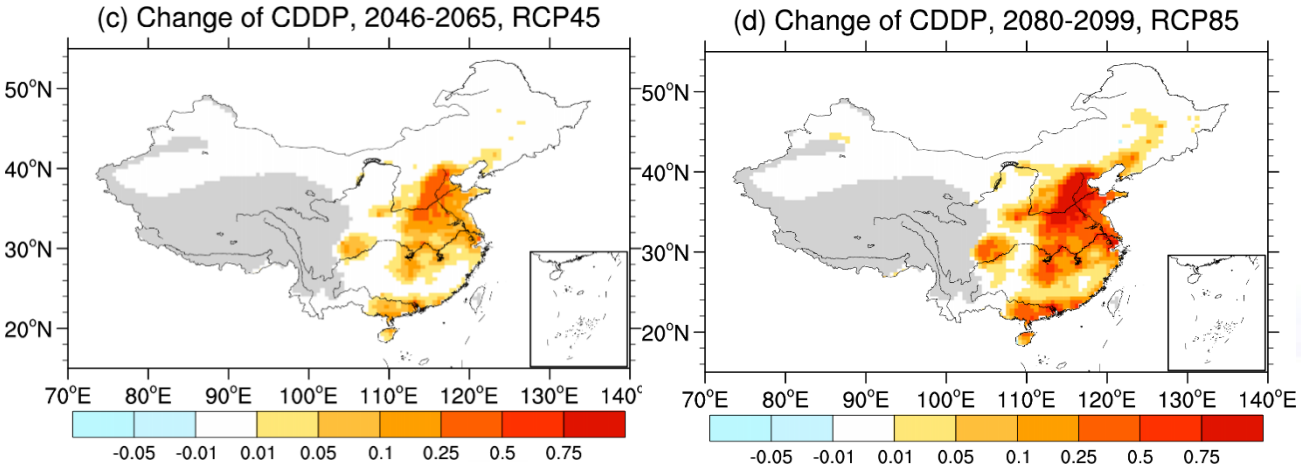
RCP8.5

HDDP



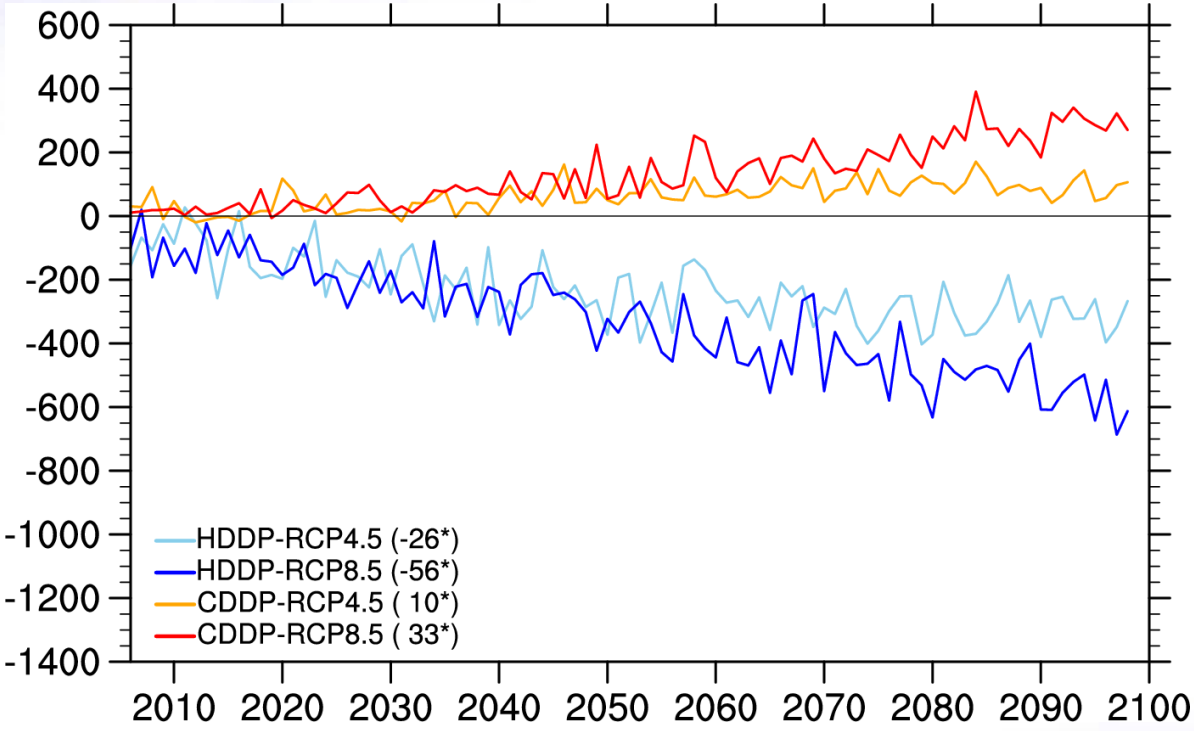
HDDP

CDDP

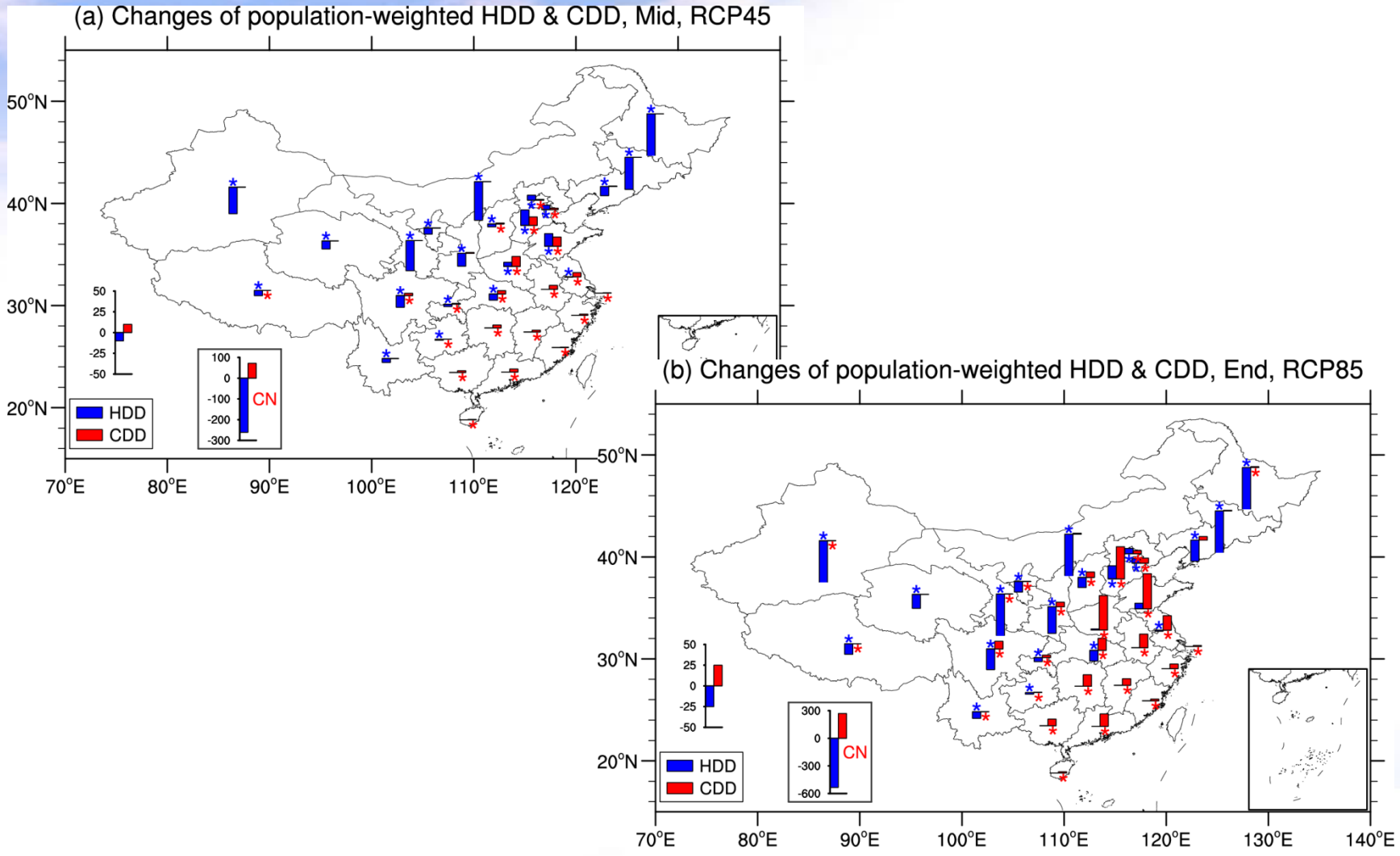


CDDP

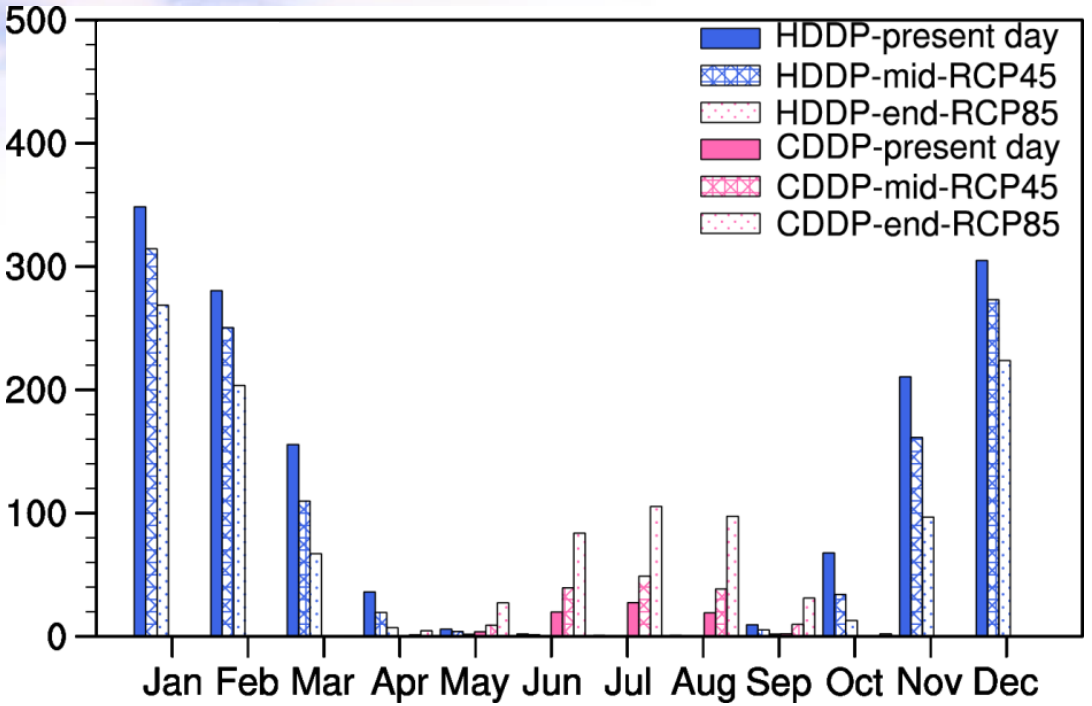
Changes of population weighted HDDP and CDDP over China (unit: ºC·d)



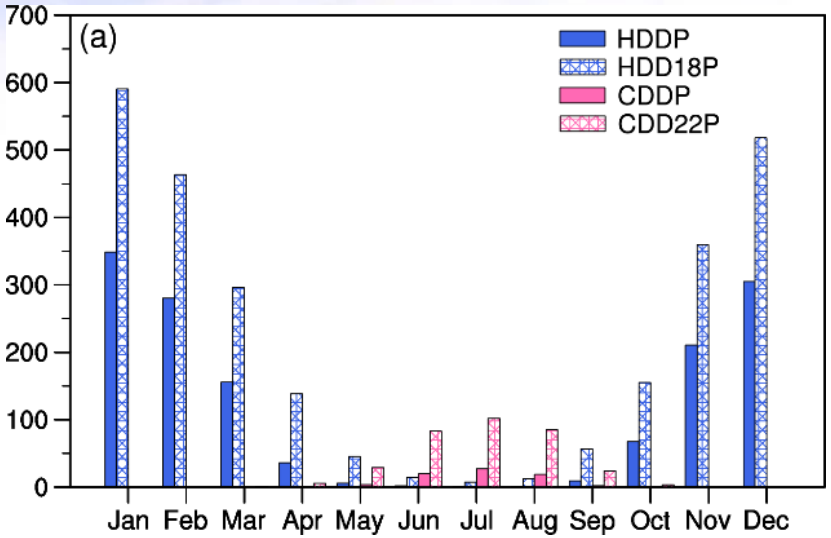
Changes of HDD/HDDP and CDD/CDDP averaged over China in the 21st century (2006-2099) (unit: ^{o}C·d)

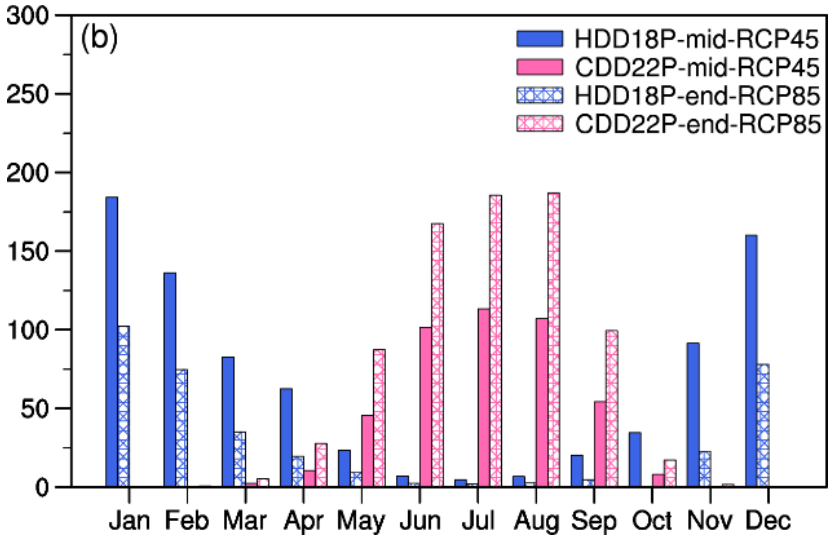


Changes of HDDP and CDDP in different provinces and the whole country (marked with CN) for (a) RCP4.5 mid-century (2046-2065), and (b) RCCP8.5 end of century (2080-2099) (b) (unit: °C·d).



Annual cycle of HDDP and CDDP for the present day (1986-2005), RCP4.5 mid 21st century and RCP8.5 end of 21st century (unit: $^{o}C \cdot d$)





Annual cycle of (a) China-mean HDDP, HDD18P and CDDP, CDD22P for the present day period (1986-2005), and (b) future changes of HDD18P and CDD22P compared to present day HDDP and CDDP, respectively, for the RCP4.5 mid century (2046-2065) and RCP8.5 end of century (2080-2099) periods (unit: $^{o}C \cdot d$)

Changes of annual mean HDDP, HDD18P and CDDP, CDD22P in the mid (2046-2065) and end (2080-2099) of the 21st century under RCP4.5 and RCP8.5 relative to the present day (1986-2005) HDDP and CDDP over China (%).

	Mid of 21st century		End of 21st century	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5
HDDP	-19	-27	-23	-39
CDDP	101	179	133	379
HDDP+CDDP	**-13**	**-17**	**-15**	**-19**
HDD18P	55	43	49	23
CDD22P	594	738	632	1049
HDD18P+CDD22P	**81**	**76**	**78**	**75**

4. Conclusions and discussions

- The model can reproduce well the present day spatial distribution and amount of HDD and CDD over the region, as well as their seasonal evolutions.
- Substantial decrease of HDD and increase of CDD. Averaged over China, the decrease in HDD is much larger than the increase in CDD, but with distinct regional variability.
- With population weighting, a larger decrease of regional mean HDD compared to the increase of CDD is projected, indicating a decrease of about 15% in potential energy demand for different periods and scenarios in the future.

- Future demand of total energy consumption shows a decrease, with less in the north for heating but more in the south for cooling. Changes in seasonal distribution are found with greater demand in the summer and lower in the winter.
- To change the HDD and CDD of current standards to the commonly used in Europe and the U.S. (18ºC and 22ºC), potentially large increases of future energy demand (~80%) are expected.
- Future multi-RCMs ensemble to address the uncertainties.
- To link of degree days to the real energy consumption (much more efforts needed)


Thank You !