Future changes of thermal comfort conditions over China based on multi-RegCM4 simulations

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Motivation:

- We investigated the observed changes of Effective Temperature (ET) over

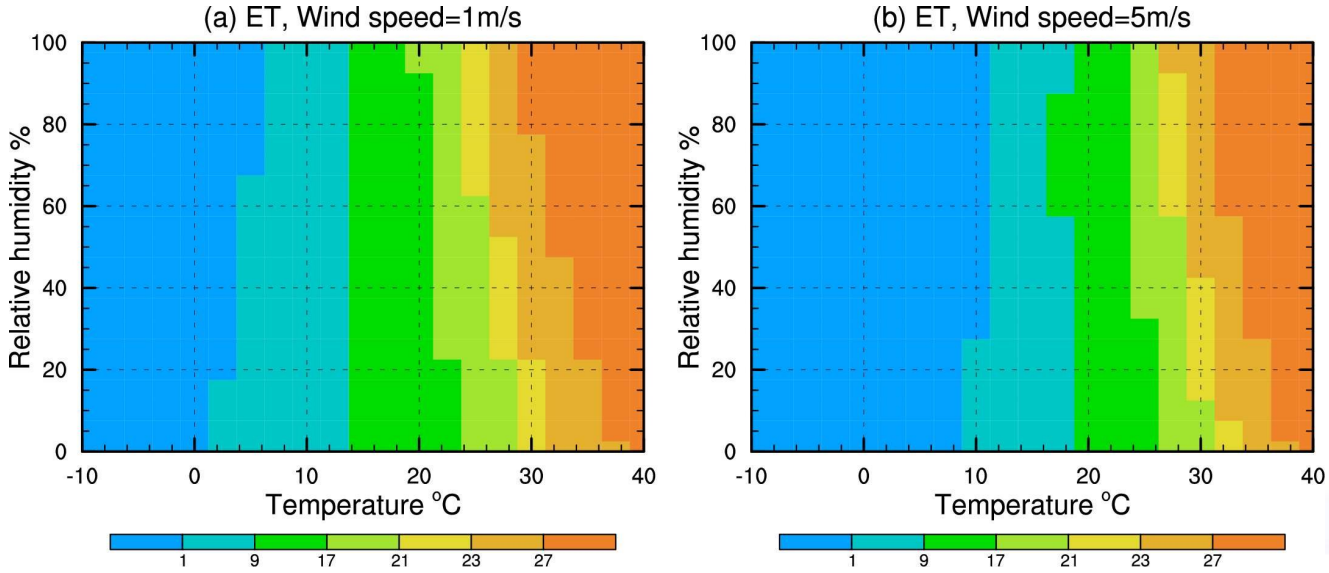
- How about the future?

Human thermal comfort

- While human comfort/discomfort, morbidity and mortality depend largely on temperature, other climate variables such as humidity and wind speed are also significant factors
- Warm conditions: high humidity reduces the evaporation (sweating) and consequently increases the heat stress. Wind accelerates perspiration, leading to an increase of evaporative cooling.
- Cold conditions: wind removes heat from the human body, leading to a chilling effect (northern China); the wetter climate in typically leads to a perception of colder conditions (southern China).
- Various biometeorological indices have been used, mostly based on the combination of the above, and possibly other variables.

➢ Effective temperature (Yaglou 1923, Missenard 1933, Gregorczuk 1968, Landsberg 1972, Hentschel 1987) :

$$ET = 37 - \frac{37 - T}{0.68 - 0.0014 \cdot RH + \frac{1}{1.76 + 1.4 \cdot v^{0.75}}} - 0.29 \cdot T \cdot (1 - 0.01 \cdot RH)$$



Behavior of ET (°C) as a function of temperature (°C) and relative humidity (%) under 1m/s (a) and 5 m/s (b) wind conditions.

(Wu et al., 2017)

➢ Assessment scale of ET:

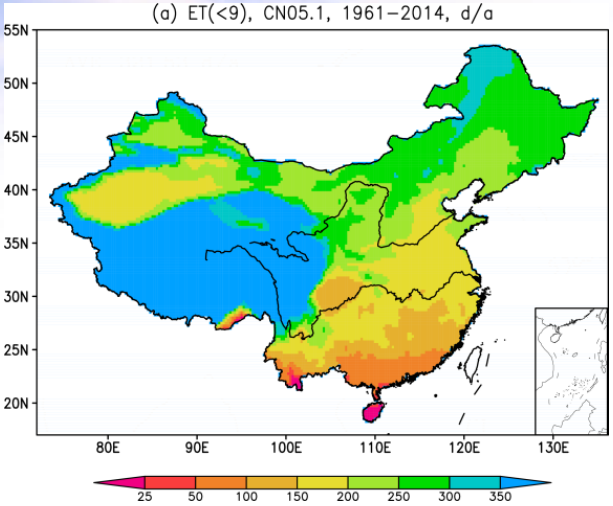
Thermal sensation	ET (°C)
very cold	<1
cold	1–9
cool	9–17
comfortable	17–21
warm	21–23
hot	23–27
very hot	>27

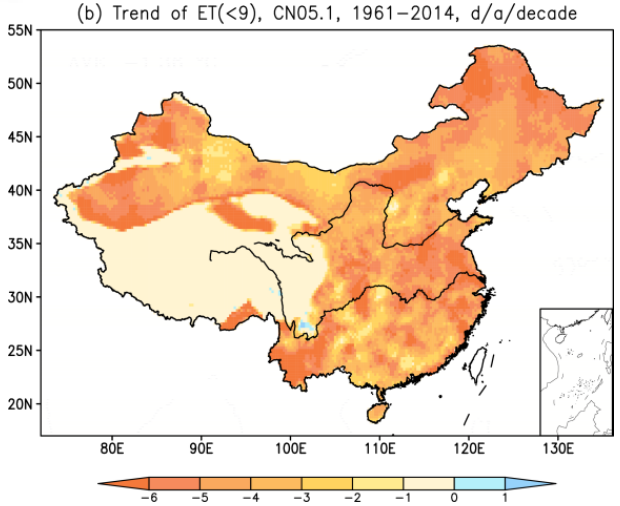
- ✓ Simplicity
- ✓ Lower demand of data
- ✓ Cover of the full thermal range from very cold to very hot conditions

Mean **Trend**

Cold days

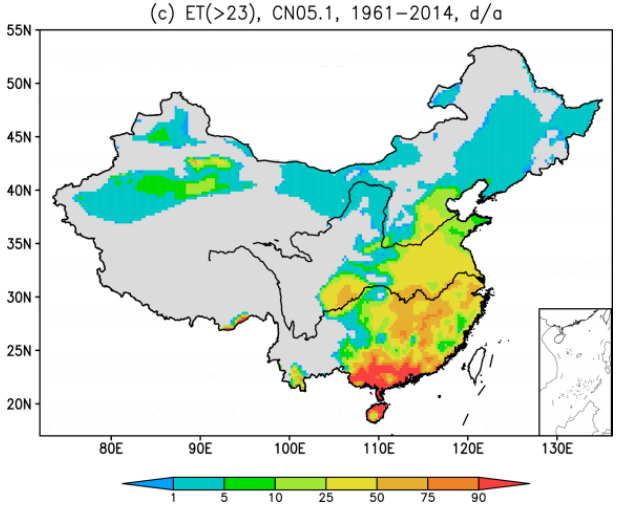
(ET<9°C)

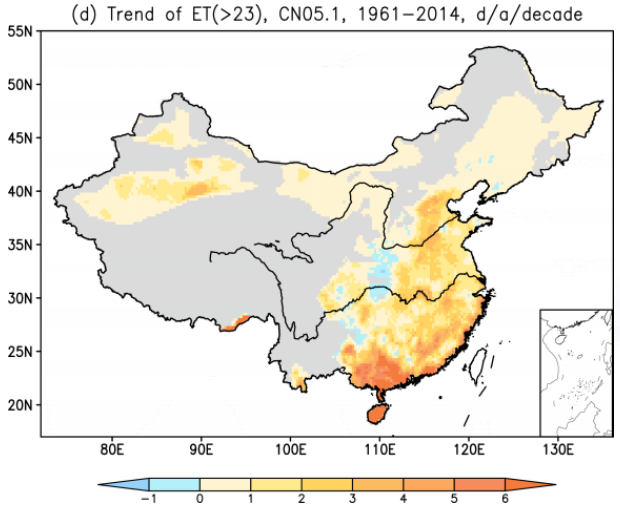




Hot days

(ET>23°C)





Spatial distribution of the annual mean (d/a) and linear trend (d/a/decade) of cold and hot days

(Wu et al., 2017)

The projection: steps

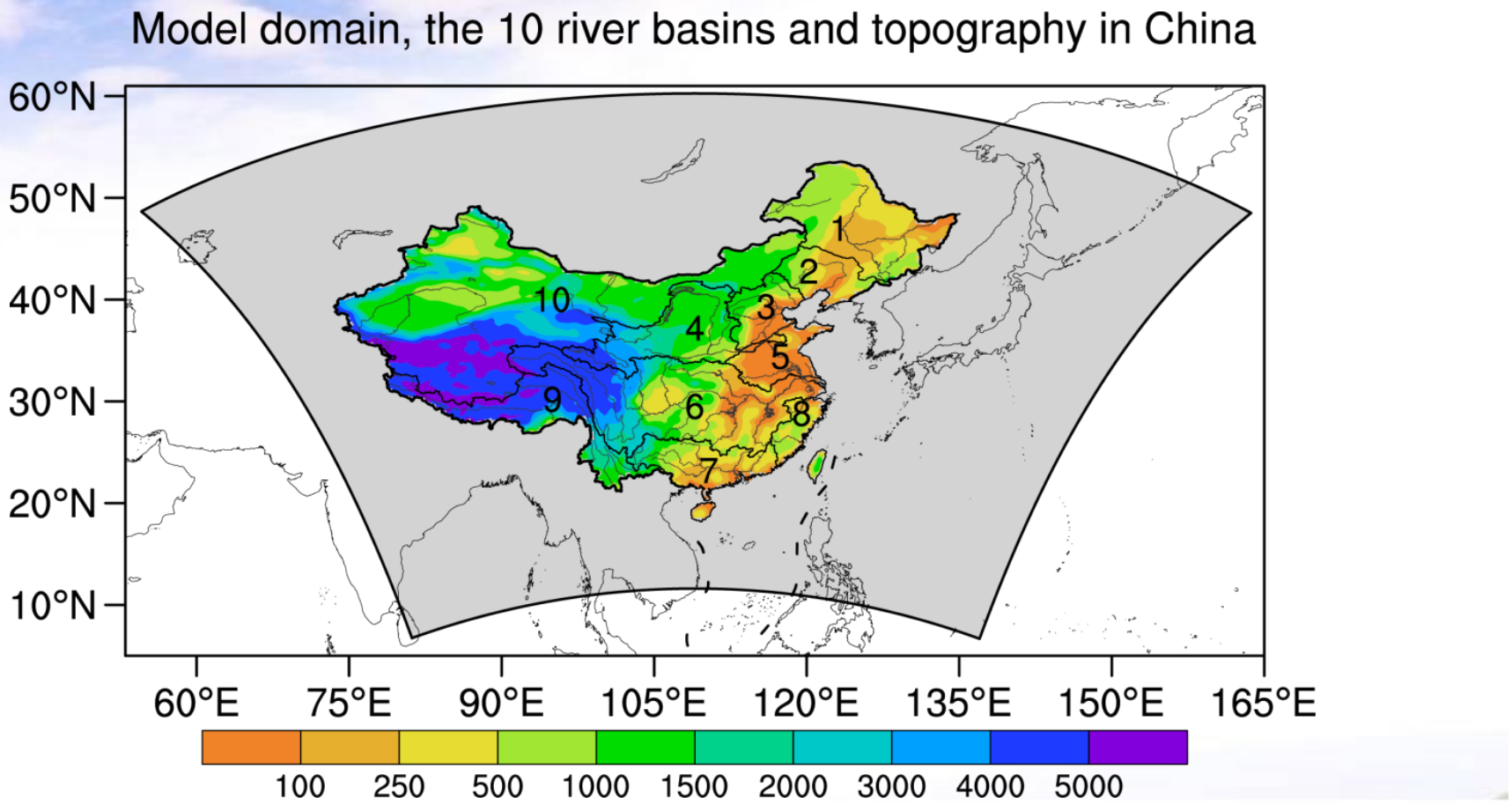
1. Selection of model physics: CLM + convection

2. Further tuning: land surface, etc.

3. Long period simulation and validation:

   driven by ERA-interim, 20 years

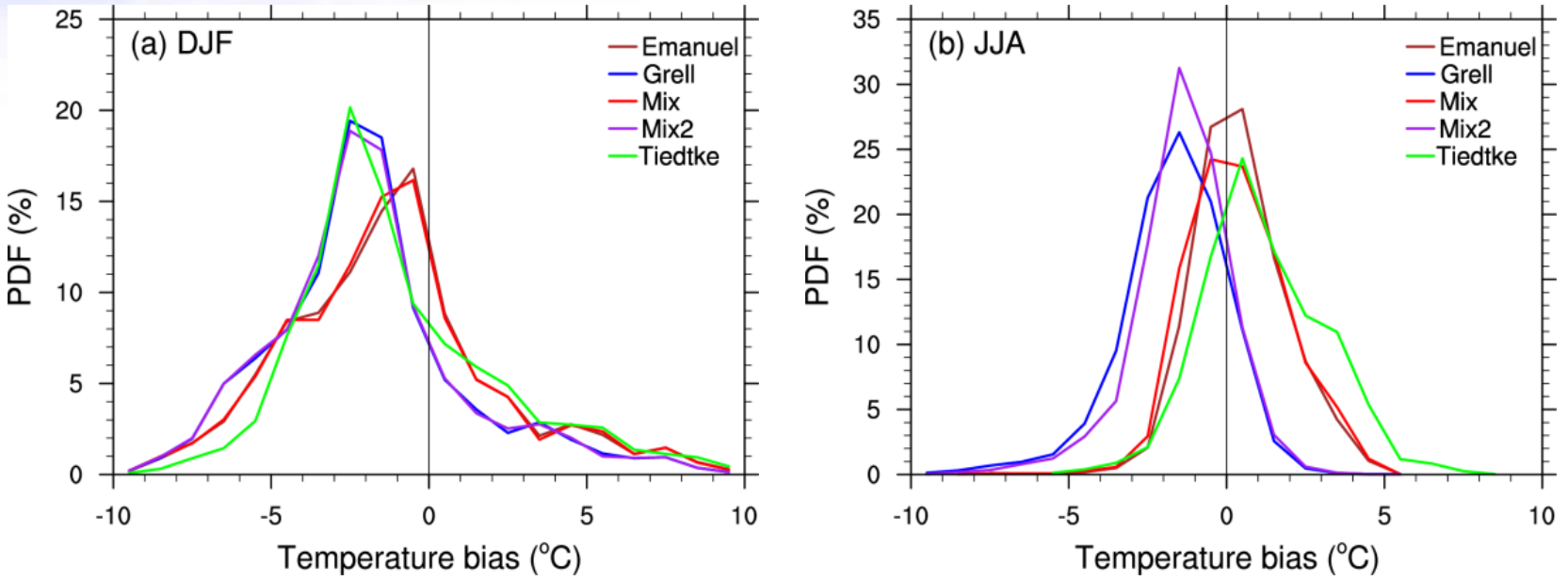
4. Climate change projections: ET changes



Model domain (gray shaded), topography (unit: m), major rivers and the 10 river basins in China

Step. 1

- Domain: CORDEX-EA (phase II), 25km resolution
- Period: 1 November 1999 to 30 November 2000
- Driving fields: ERA-interim
- Model version: RegCM4.4
- CLM3.5 with different convections:
  (1) Emanuel,
  (2) Grell,
  (3) Emanuel over land and Grell over ocean (Mix),
  (4) Grell over land and Emanuel over ocean (Mix2)
  (5) Tiedtke (TDK)



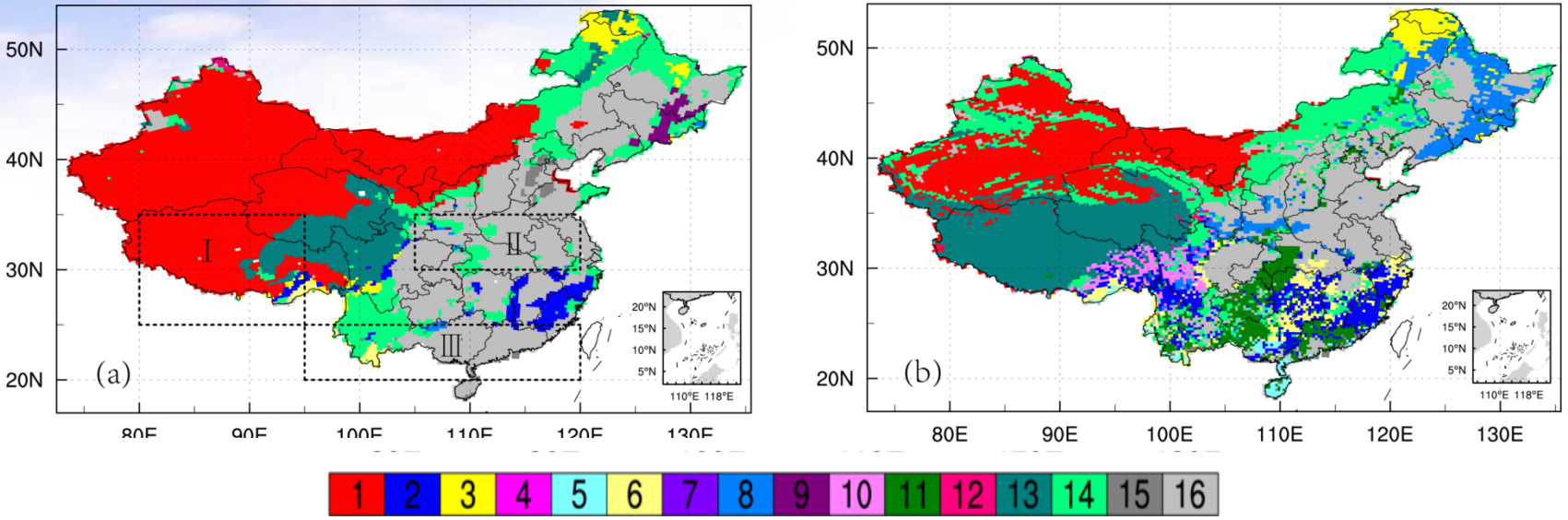
Probability density function distributions (%) of temperature bias in DJF (a) and JJA (b) (ºC)

(Gao et al., 2016)

Step 2. Further tuning (land surface etc.)

- **Vegetation cover**

- **The surface emissivity**
  - ✓ **For bare soil and snow in CLM: 0.96 and 0.97**
  - ✓ **Changed to 0.80 and 0.92 following observation literatures**
  - ✓ **Reduced effectively the cold bias in DJF**



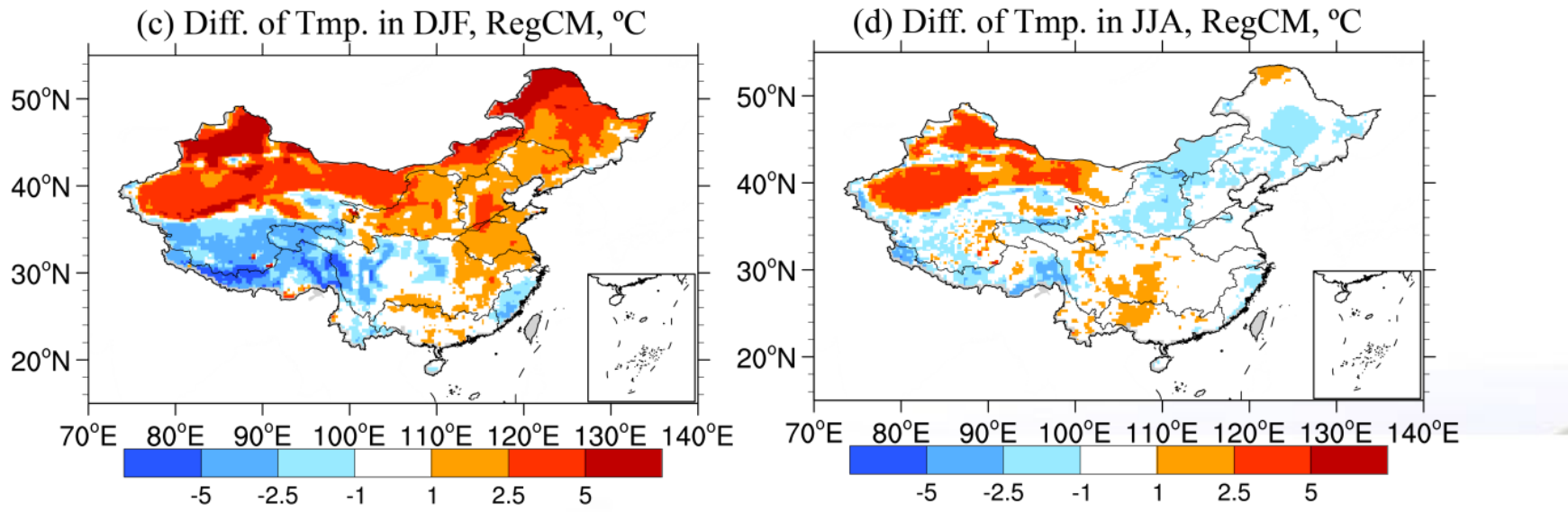
The distribution of land cover (bare ground and vegetation) with the largest area fraction in China: (a) ORG, (b) VEG.

1 Bare ground, 2 Temperate needleleaf evergreen tree, 3 Boreal needleleaf evergreen tree, 4 Boreal needleleaf deciduous tree, 5 Tropical broadleaf evergreen tree, 6 Temperate broadleaf evergreen tree, 7 Tropical broadleaf deciduous tree; 8 Temperate broadleaf deciduous tree, 9 Boreal broadleaf deciduous tree, 10 Temperate broadleaf evergreen shrub, 11 Temperate broadleaf deciduous shrub, 12 Boreal broadleaf deciduous shrub, 13 C_3 arctic grass, 14 C_3 grass, 15 C_4 grass, 16 Crop

(Han et al., 2015)

Step 3. Long period simulation and validation

- **Resolution: 25km×25km**
- **Period: Jan 1, 1990 to 31 Dec 2010**
- **Driving fields: ERA-interim**



Temperature bias in DJF and JJA

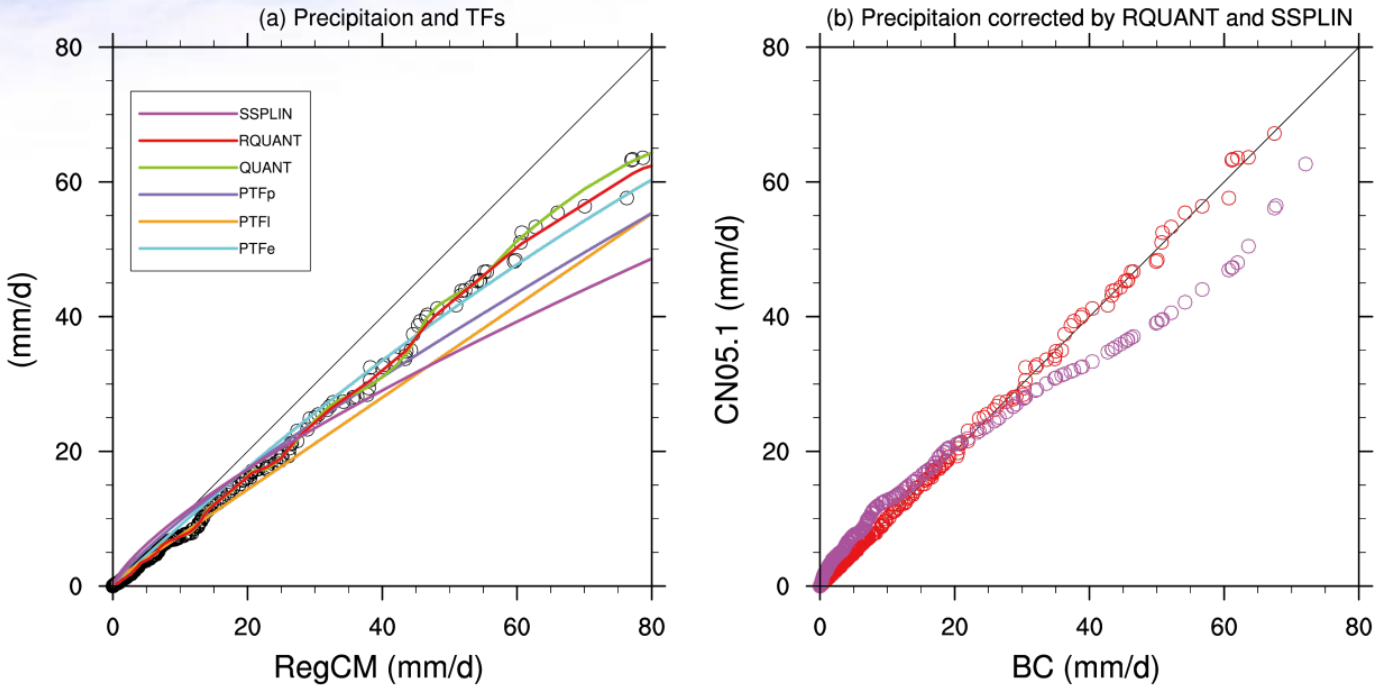
(Gao et al., 2017)

Step 4. Climate change projections

RCM	GCM	Time	Exp.
RegCM-v4.4	ERA-Interim	1990-2010	Evaluation
	EC-EARTH	1979-2099	Hist., RCP4.5&8.5
	MPI-ESM-MR	1979-2099	Hist., RCP4.5&8.5
	HadGEM2-ES	1960-2099	Hist., RCP4.5&8.5
	CSIRO-Mk3.6	1960-2099	Hist., RCP4.5&8.5

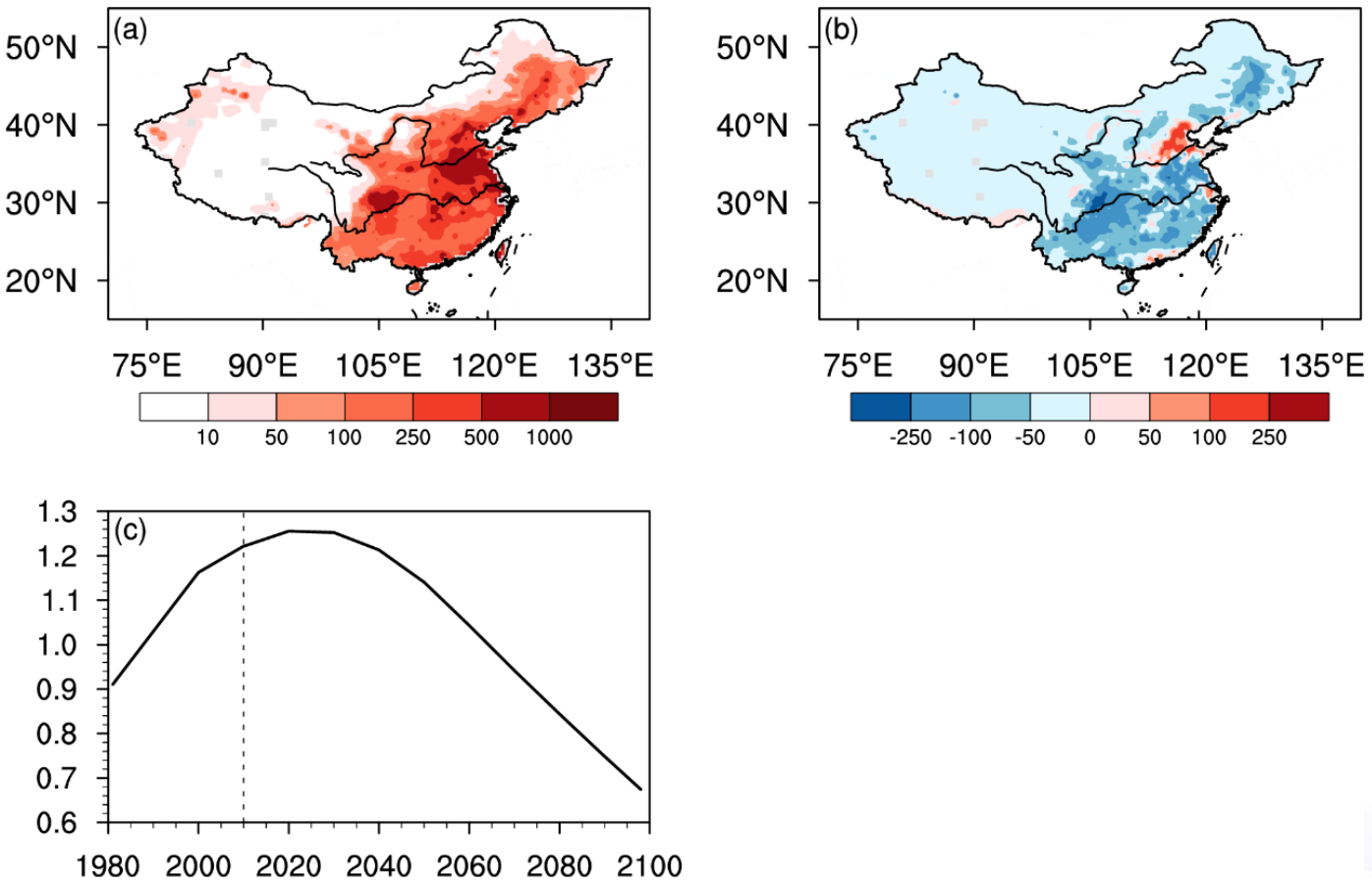
+ RCP2.6

➢ Bias Correction: quantile mapping



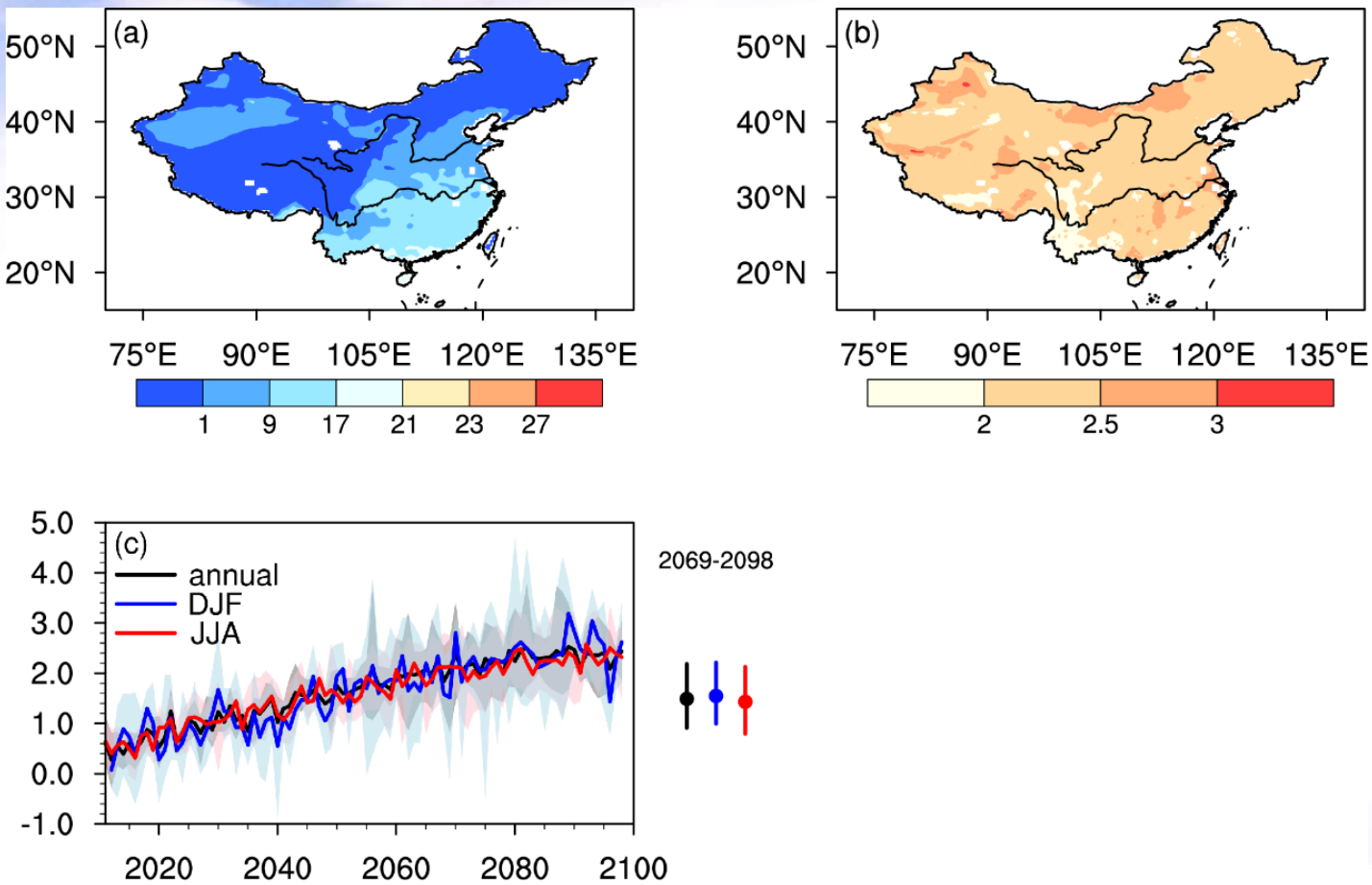
Transfer functions and simulated/bias corrected precipitation at a grid point in JJA: (a) The observations and transfer functions of six methods; (b) the bias corrected precipitation by RQUANT (red) and SSPLIN (purple) methods. In Fig. a, the x-axis represents simulations, and y-axis represents observations for the black circles and bias corrected simulations for the curves. In Fig. b, the x- and y-axis represent simulation and observation

(Tong et al., 2017)

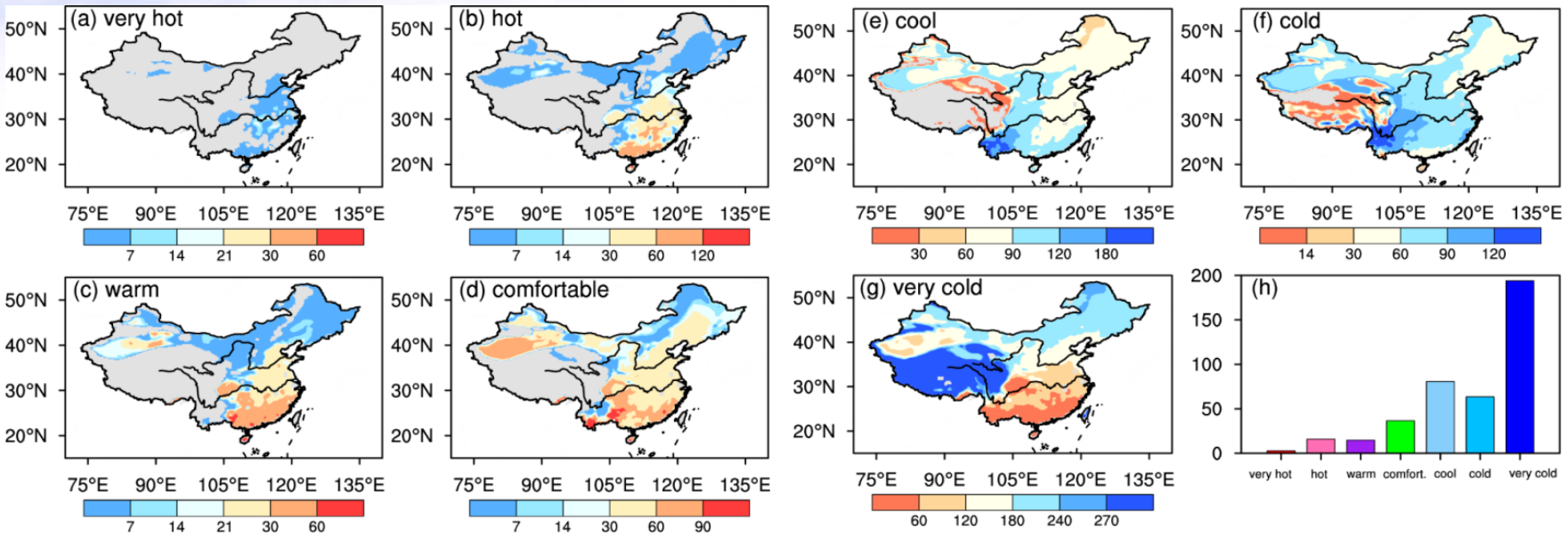


Spatial distribution of population density (10^3 inhabitants per square grid) of present day and future changes

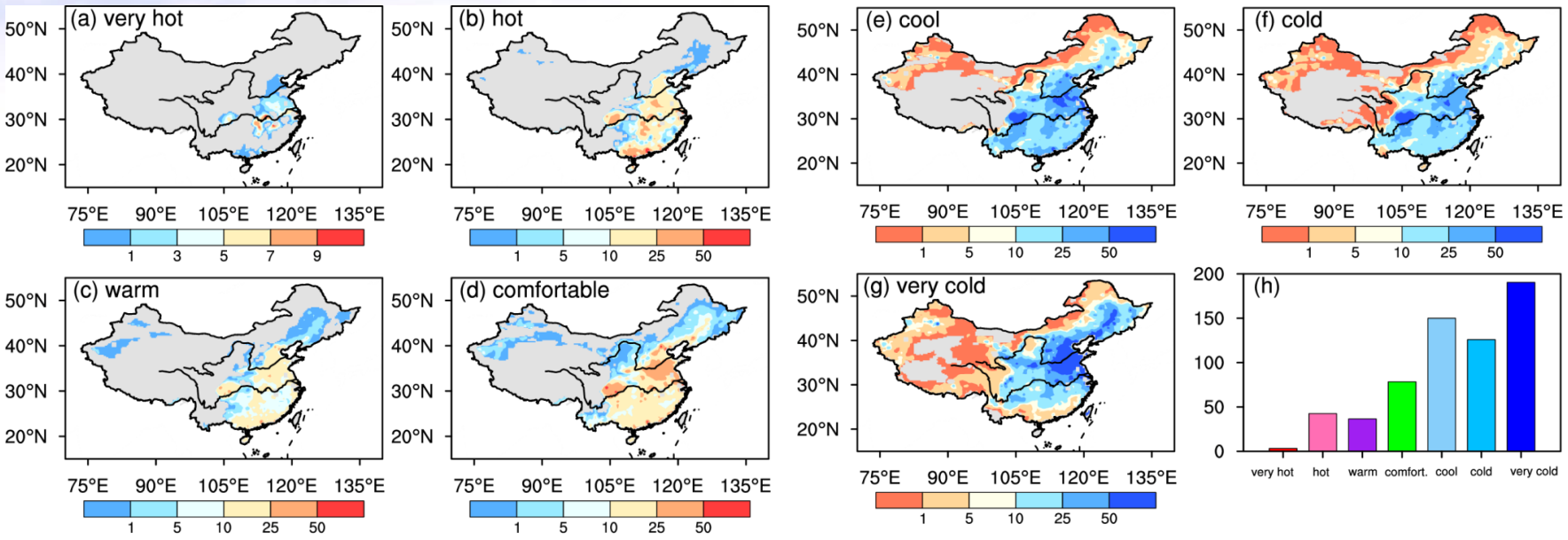
(Gao et al., 2019)



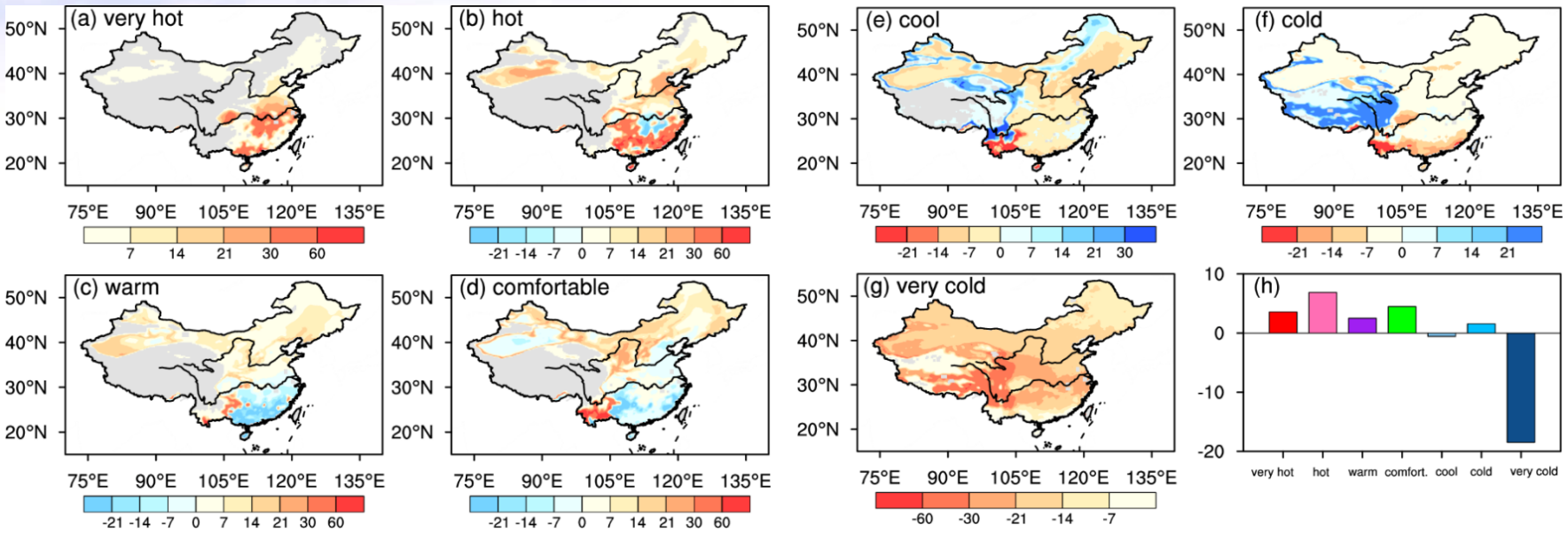
Ensemble average annual mean ET of the present day (1980-2010) and future (2069-2098) changes (°C)



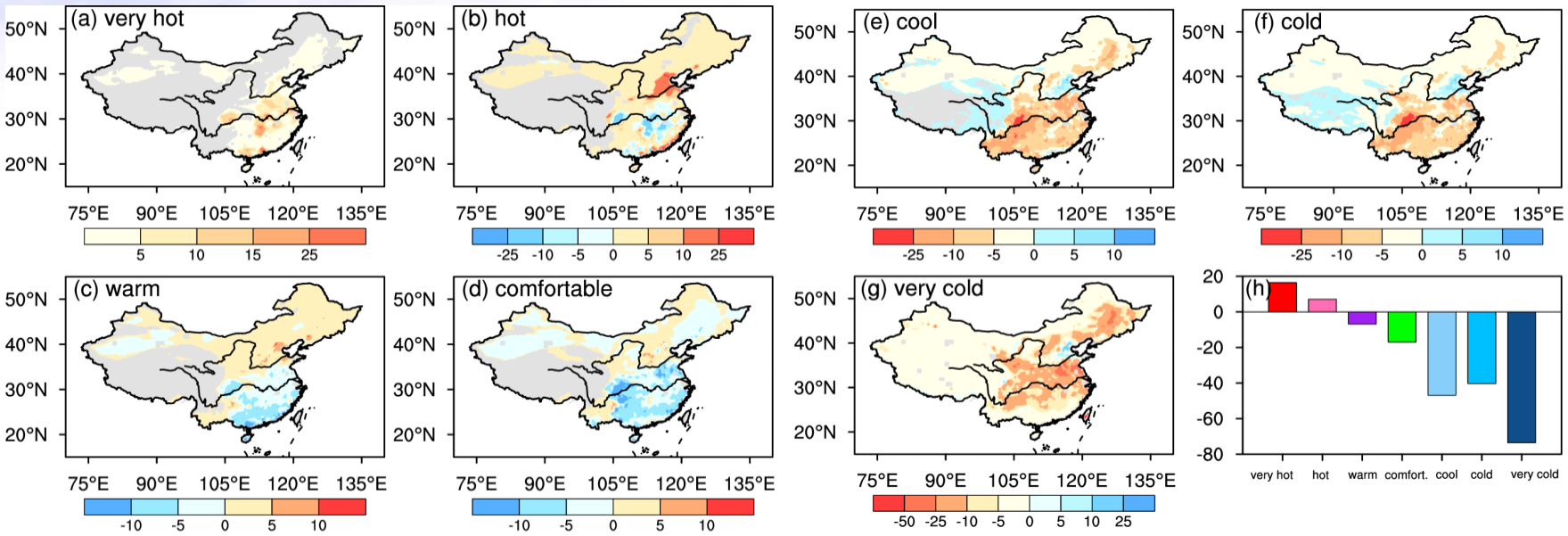
Ensemble average days of different thermal comfort categories in present day (days)



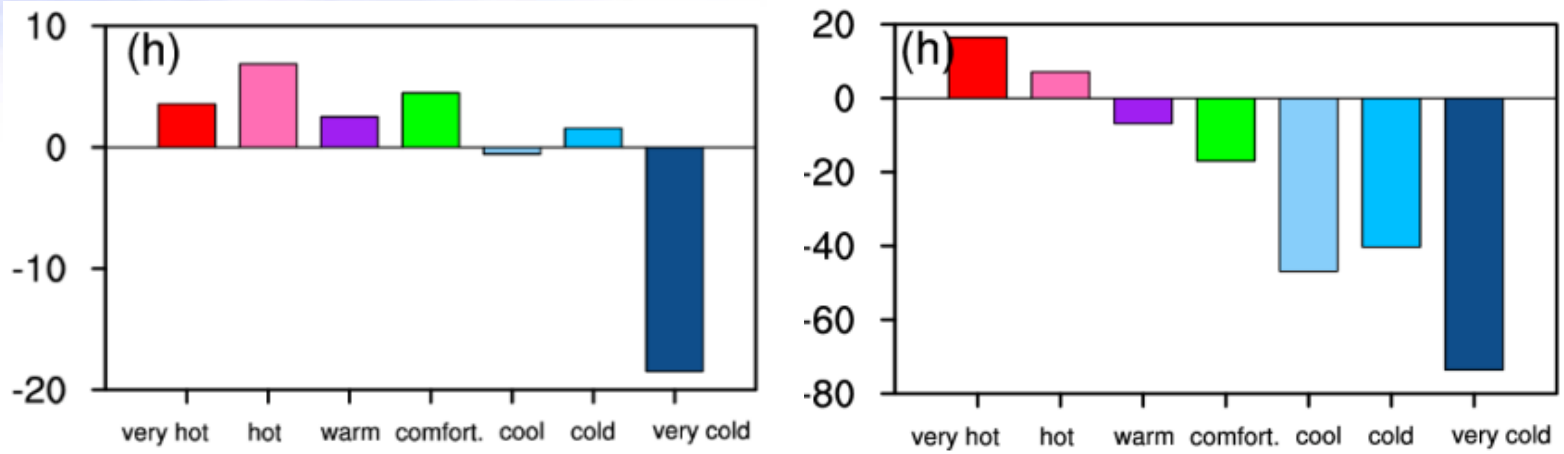
Ensemble average person-days of different thermal comfort categories in present day conditions (10^6 for a-g and 10^9 person-days for h)



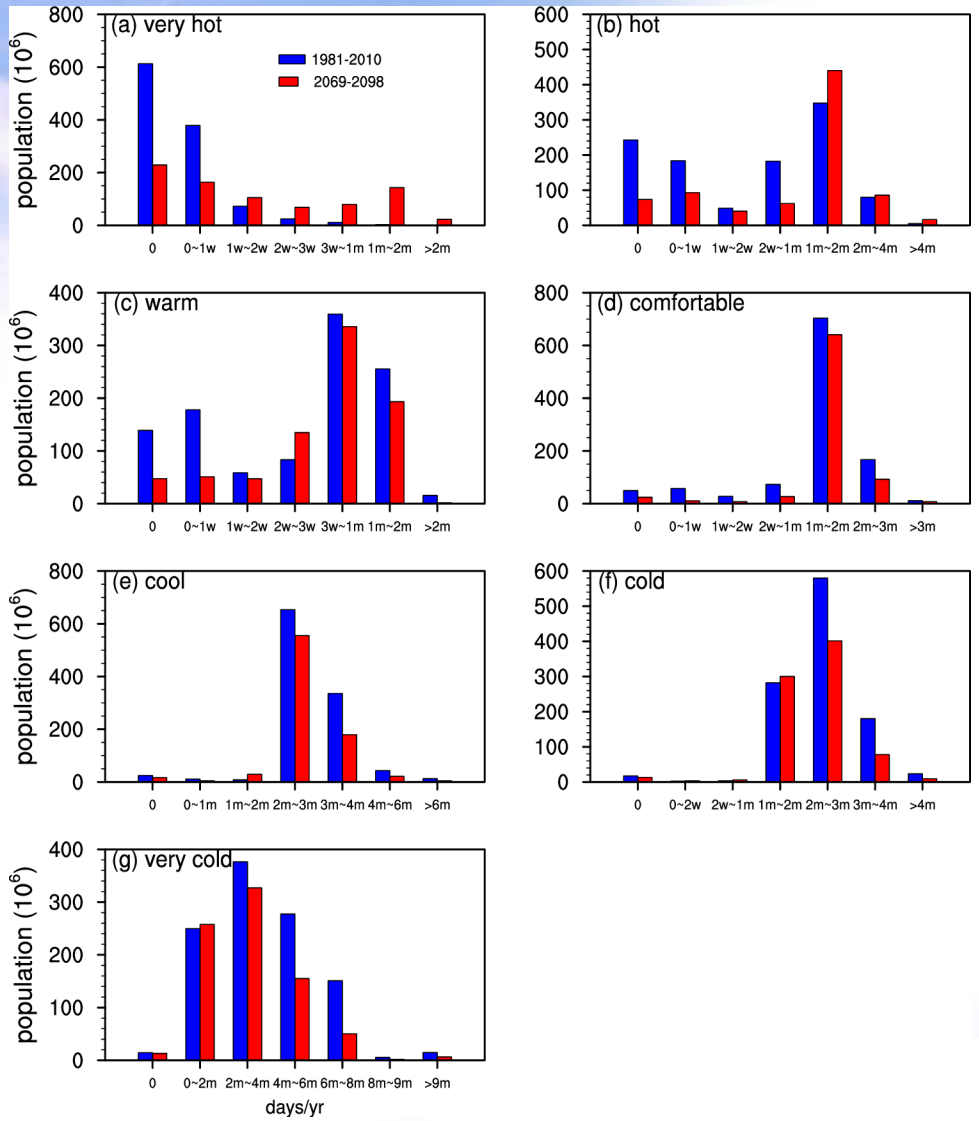
Projected changes of ensemble average days in different thermal comfort categories by the end of the 21st century (days)



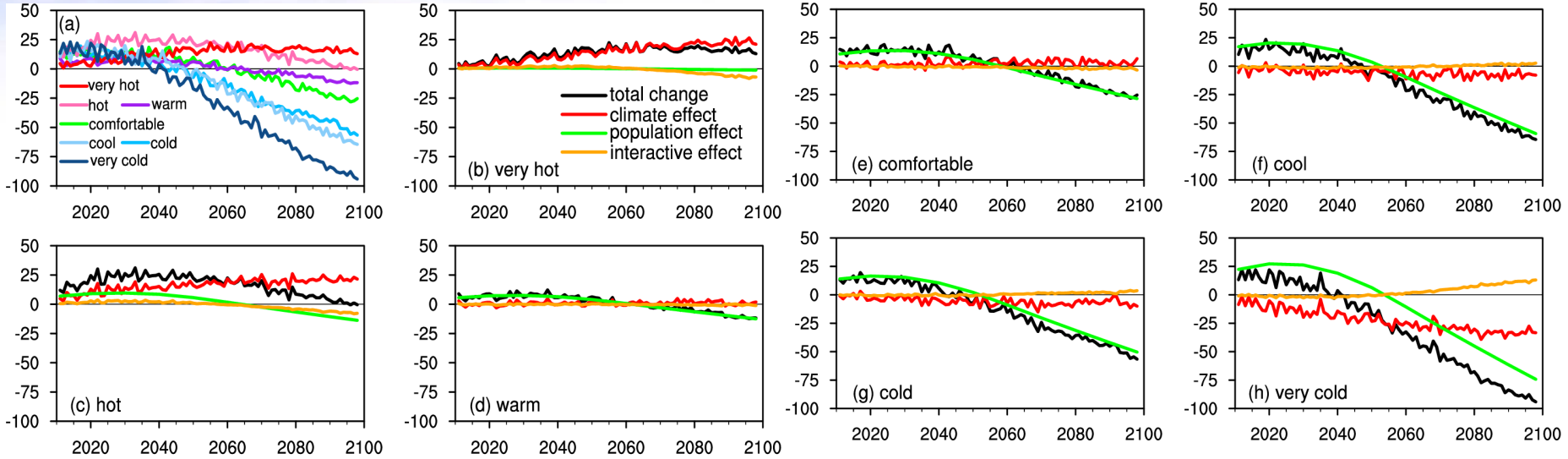
Projected changes of ensemble average person-days in different thermal comfort categories by the end of the 21st century (10^6 for a-g and 10^9 person-days for h)



Comparison of the regional mean projected days and person-days in different thermal comfort categories by the end of the 21st century (days)



Amount of population subjected to different numbers of days in a given thermal comfort category for present day and future (10^6 persons). The "w" and "m" on the X-axis represent week and month



Temporal evolution of ensemble average person-days in different thermal comfort categories and contributions from climate, population, and interactive effects (10^9 person-days).

Future work

- More analysis of the simulations: temperature, precipitation, extremes
- Working on temperature simulation and projection: connection of biases / climate change signal from GCM and RCM
- …
- Distribution to the climate and impact society

Future work: RCP2.6 + NorESM

RCM	GCM	Time	Exp.
RegCM-v4.4	ERA-Interim	1990-2010	Evaluation
	EC-EARTH	1979-2099	Hist., RCP4.5&8.5
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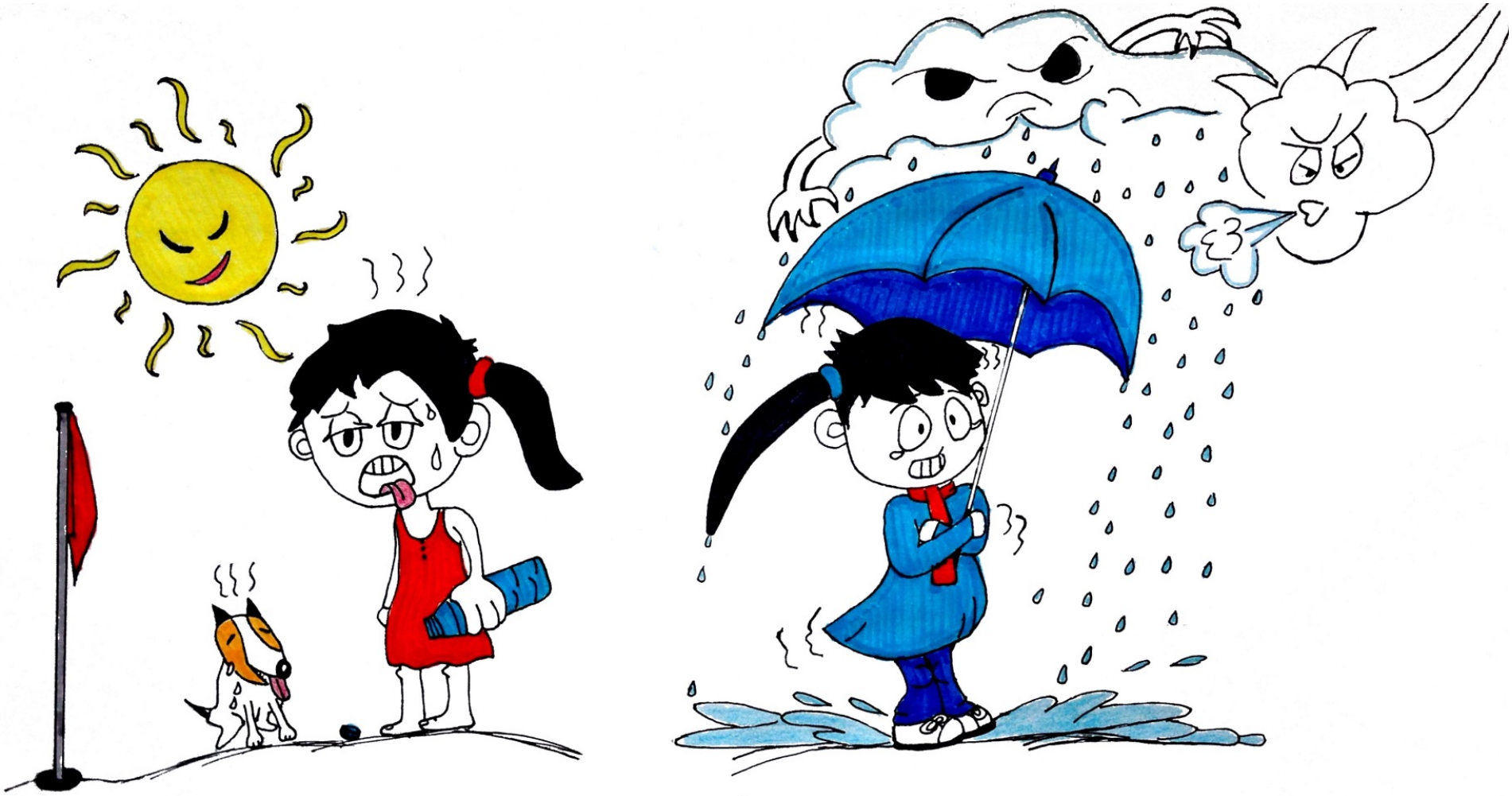

谢谢 / Grazie / Thanks!