Calibration and bias correction of climate projections for crop modelling: An idealised case study over *Europe*

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Motivation for this paper: Produce a crop yield projections.

Data: atmosphere-ocean global climate model(AOGCM)
A QUMP (Quantifying Uncertainty in Model Predictions) ensemble of AOGCM simulations

Methods: Bias correction *vs.* Change factor

Results: 'Perfect Sibling framework': use reference period data from one AOGCM simulation as pseudo-observations, and attempt to predict the future evolution of that simulation sing other independent simulation.

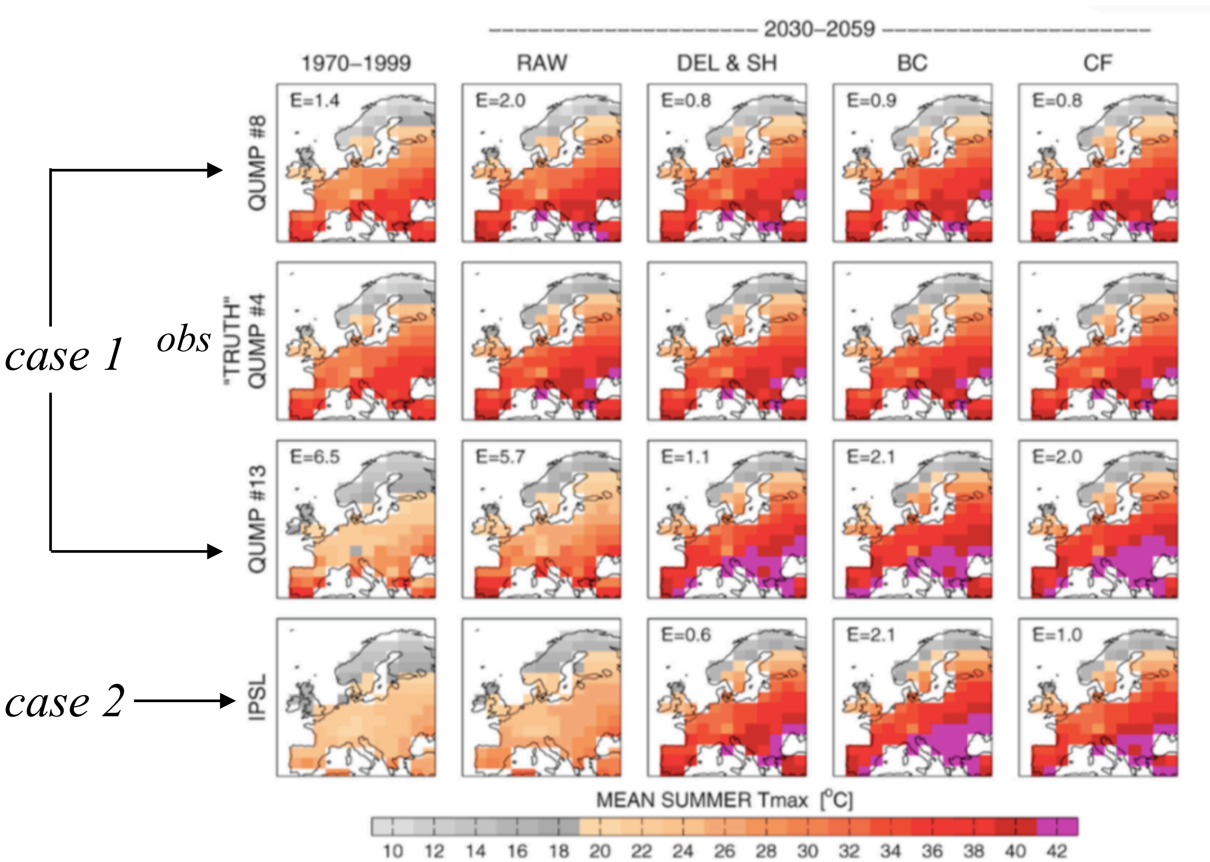

Fig. 3. Demonstrating the calibration methodologies using a range of AOGCM simulations for mean summer T_{max}. QUMP4 is selected to act as 'truth' for verification against the calibrated projections using other QUMP members (#8, #13) and the IPSL data. The RMS error for the region shown is given as the E value. Columns (from left to right) represent T_{REF}, T_{RAW}, T_{DEL} and T_{SH}, T_{BC}, and T_{CF}.

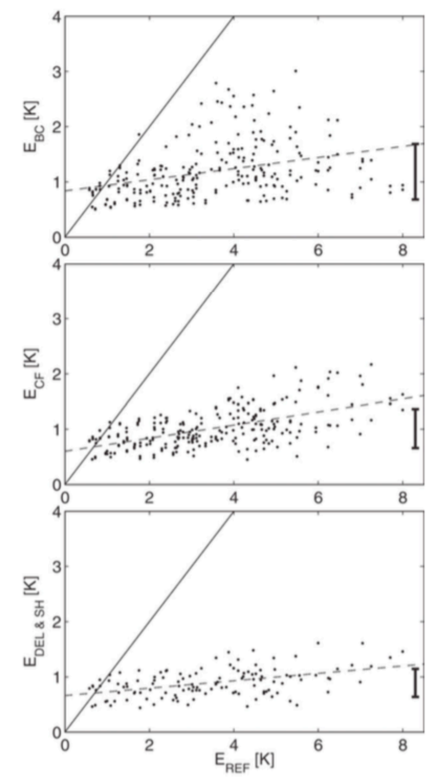

Fig. 4. The relationship between model bias and calibration ability for mean JJA T_{max}. Shown is the RMS error (E) for each calibration method (rows) for each of the 240 combinations of QUMP ensemble pairs (dots), as a function of the RMS error (E_{REF}) in the reference period, which is a measure of the model bias. The solid line shows equal errors in calibrated and reference periods. The dashed line is the regression of the QUMP ensemble members; the slopes of which are positive suggesting that the smaller the model bias, the smaller the error in calibrated mean temperatures. 95% of the dots lie to the right of the solid lines demonstrating that calibration has improved the projection.

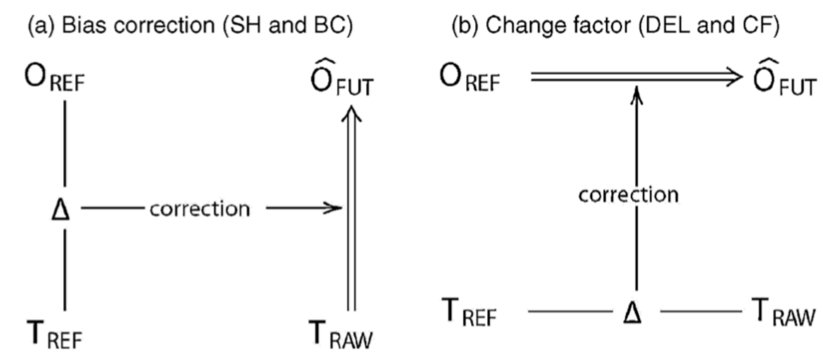

Fig. 2. Schematic of the two general types of calibration. (a) Bias correction uses raw model output and corrects it using the differences (Δ) between reference data from the model and observations. If no correction is used then this is the RAW method. (b) Change factor uses present day observations, corrected using the differences between present and future model data. The corrections considered here include changes in only the mean (SH and DEL) or mean and variance together (BC and CF).

$$T_{SH}(t) = T_{RAW}(t) + (\overline{O_{REF}} - \overline{T_{REF}})$$

$$T_{BC}(t) = \overline{O_{REF}} + \frac{\sigma_{O,REF}}{\sigma_{T,REF}}(T_{RAW}(t) - \overline{T_{REF}})$$

$$T_{DEL}(t) = O_{REF}(t) + (\overline{T_{RAW}} - \overline{T_{REF}})$$

$$T_{CF}(t) = \overline{T_{RAW}} + \frac{\sigma_{T,RAW}}{\sigma_{T,REF}}(O_{REF}(t) - \overline{T_{REF}})$$

Conclusions:

1. RMSEs between the calibrated projections and the reference simulation has decreased significantly from the uncalibrated case.
2. These results therefore favor the change factor('delta') methods over the bias correction('nudging') methods.

DEL and SH are slightly more accurate for this particular domain, with E=0.89±0.25K. CF and BC have E=1.01±0.35K and E = 1.18 ± 0.50 K, respectively. For raw projections, E = 3.26 ± 1.60 K.

Report

2020.2.27

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Results

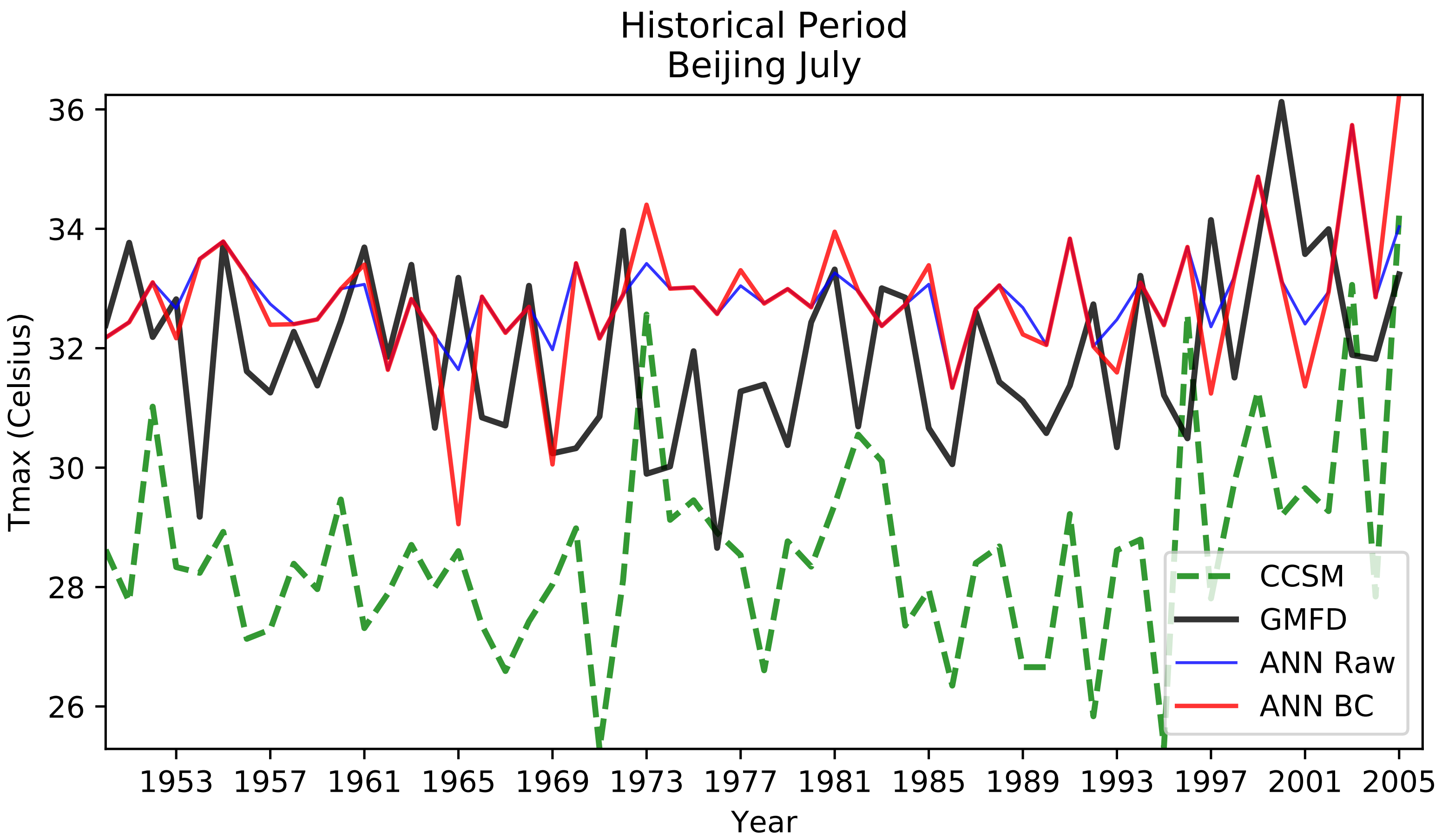
Beijing Tmax

Historical Period

mean_ccsm = 28.612423
mean_ground = 31.921953
mean_ann_raw = 32.856594
mean_ann_bc = 32.781597

std_ccsm = 1.7578304
std_ground = 1.4520789
std_ann_raw = 0.7223801
std_ann_bc = 1.1150203

rmse_ccsm = 3.949551
rmse_ann_raw = 1.8095402
rmse_ann_bc 1.9722866



Results

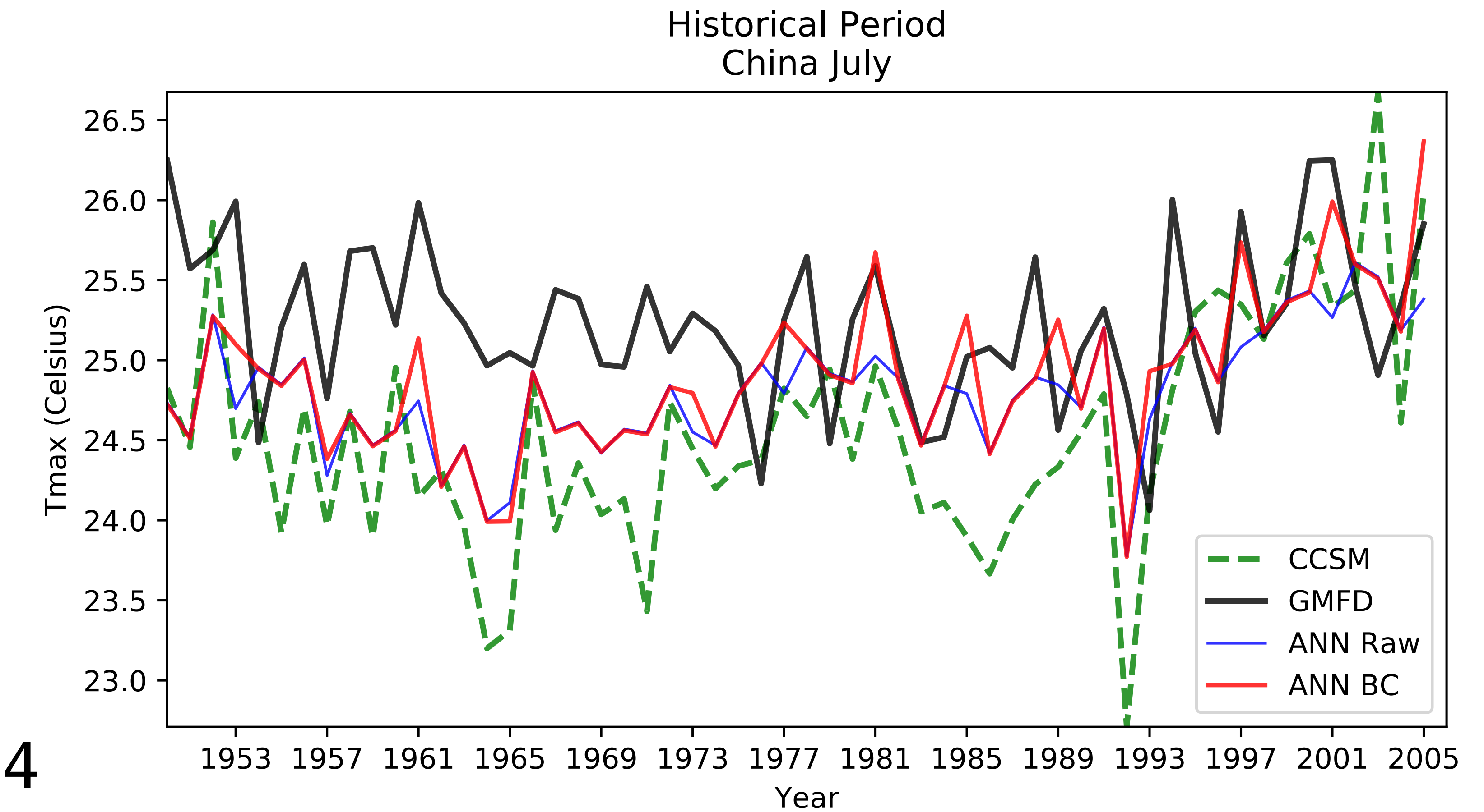
China Tmax

Historical Period

```
mean_ccsm =  24.545729
mean_ground =  25.242002
mean_ann_raw =  24.801483
mean_ann_bc =  24.896358

std_ccsm =  0.7186829
std_ground =  0.4995916
std_ann_raw =  0.37120652
std_ann_bc =  0.47796756

rmse_ccsm =  1.0220927
rmse_ann_raw =  0.69402134
rmse_ann_bc = 0.65698606
```



Results

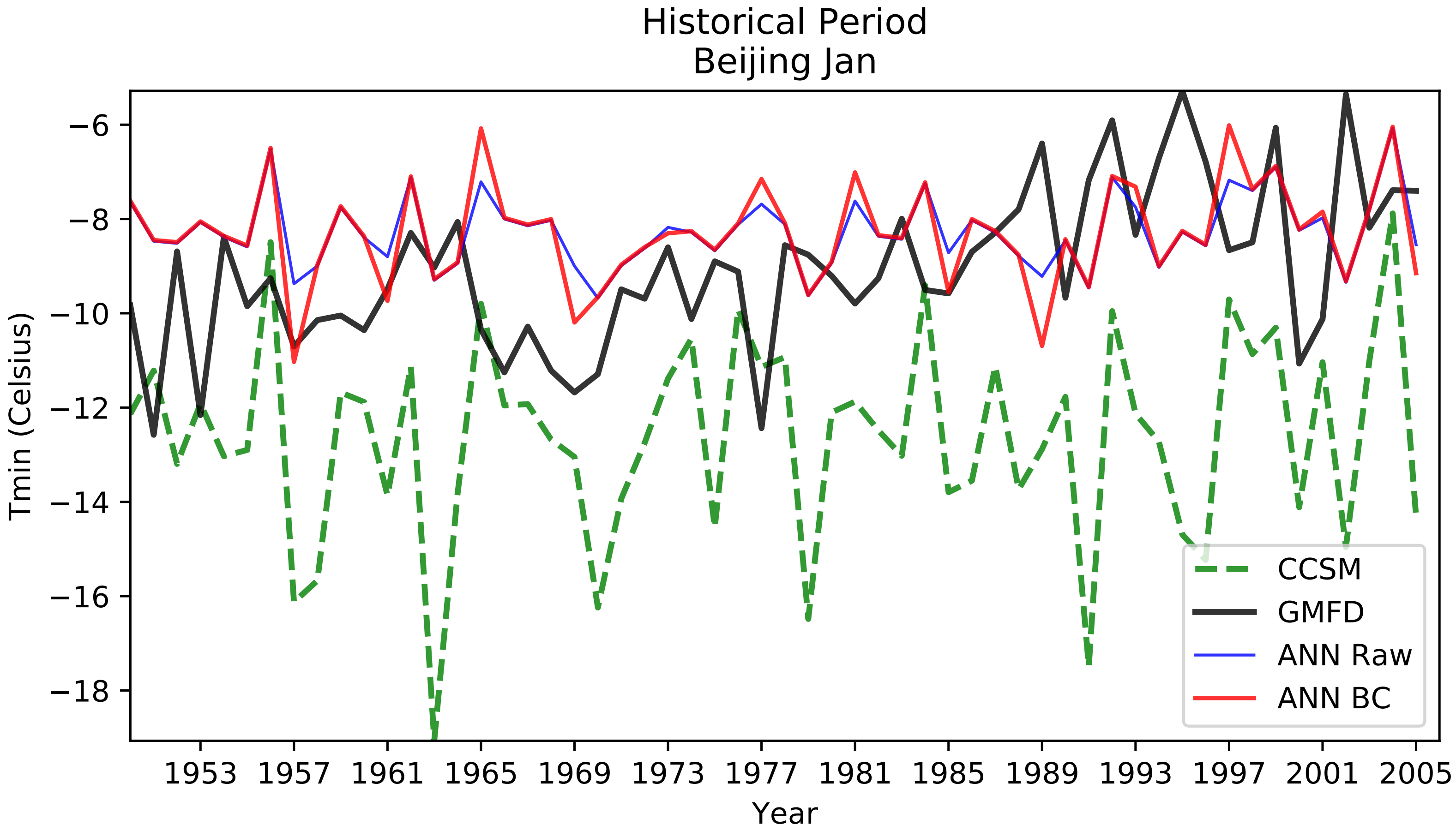
Beijing Tmin

Historical Period

```
mean_ccsm =  -12.599457
mean_ground =  -9.066935
mean_ann_raw =  -8.267509
mean_ann_bc =  -8.299951

std_ccsm =  2.1791046
std_ground =  1.6685536
std_ann_raw =  0.76728755
std_ann_bc =  1.0512749

rmse_ccsm =  4.53046
rmse_ann_raw =  1.9807148
rmse_ann_bc =  2.1052735
```



Results

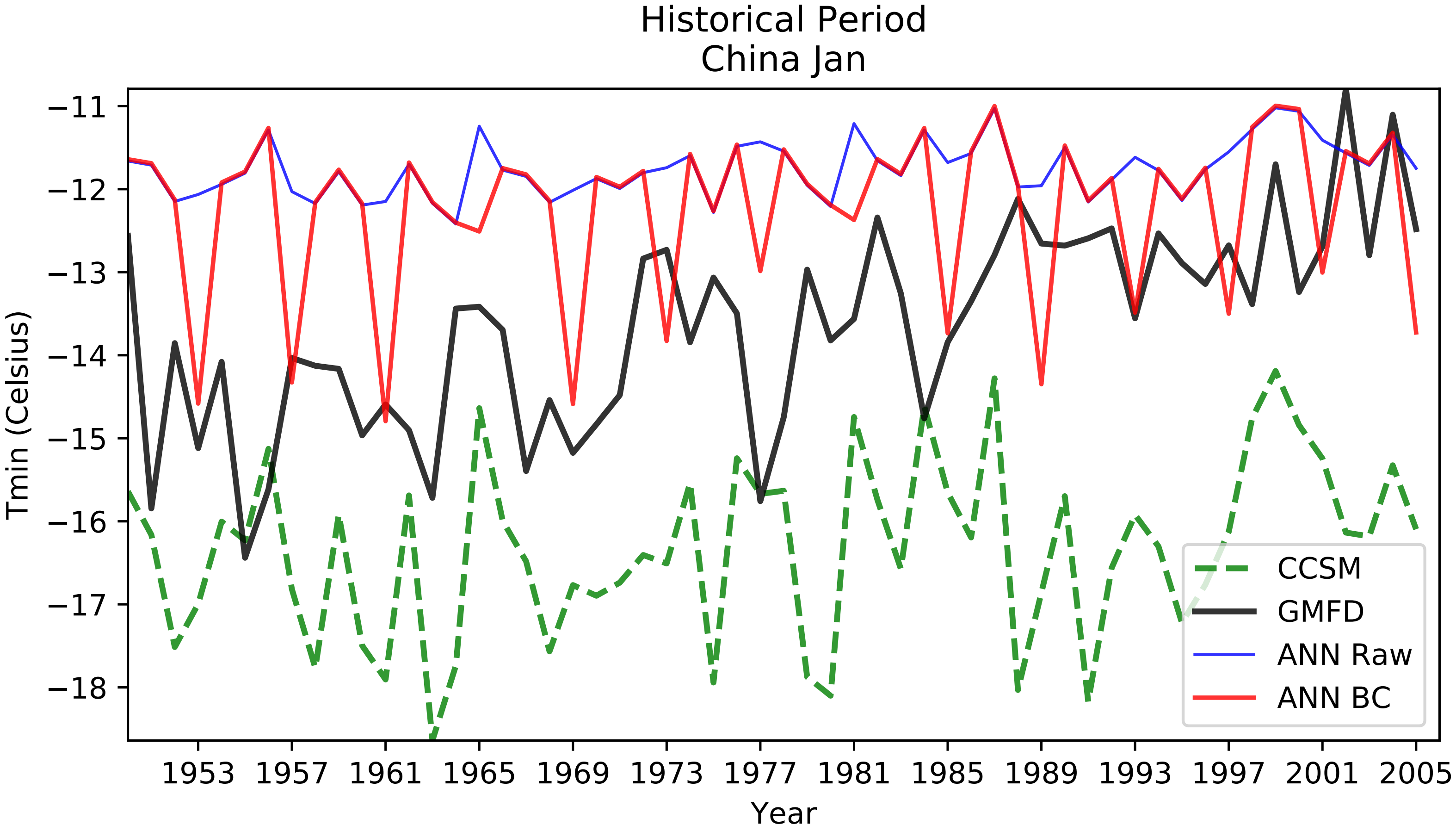
China Tmin

Historical Period

mean_ccsm = -16.318928
mean_ground = -13.636529
mean_ann_raw = -11.74804
mean_ann_bc = -12.231624

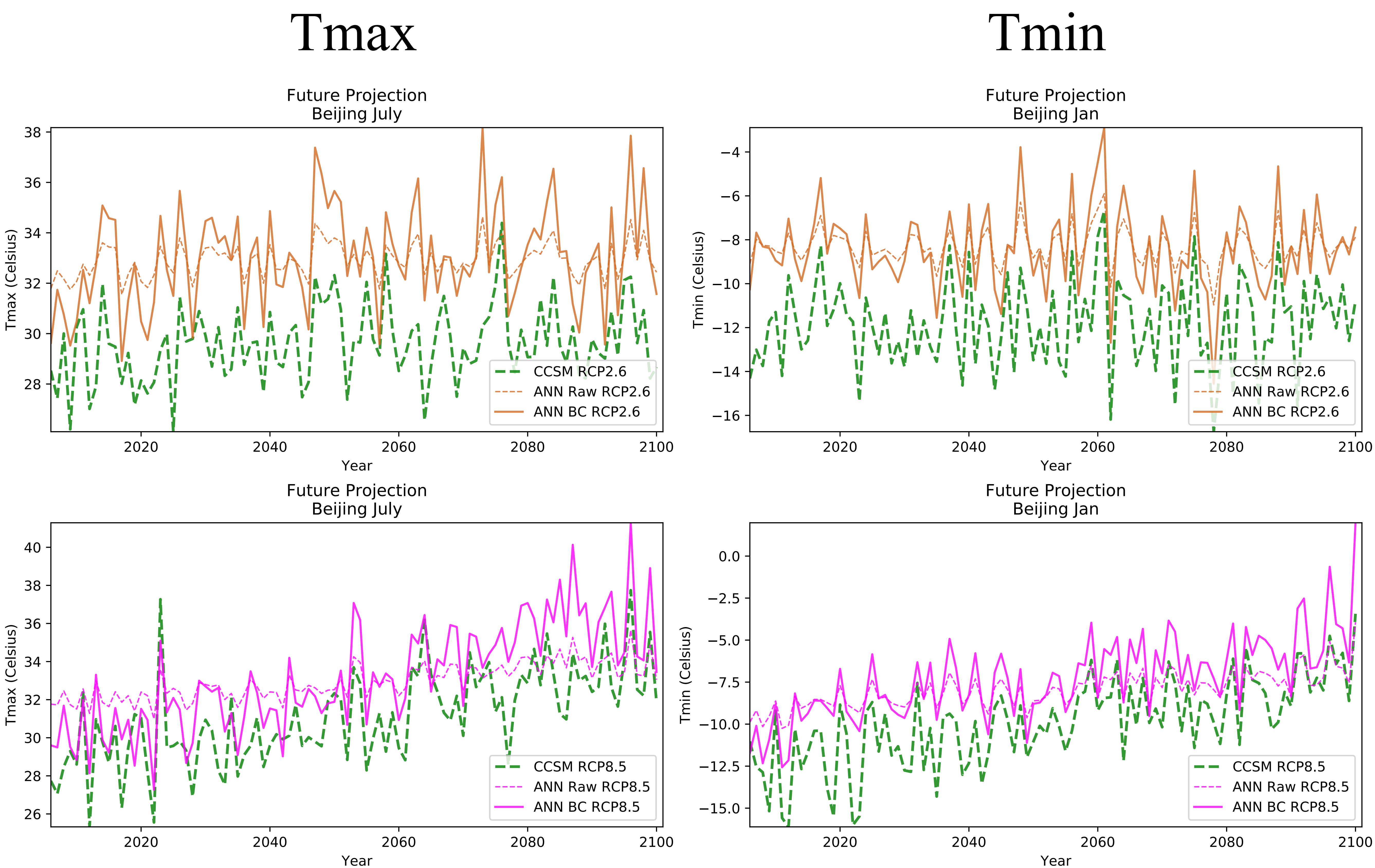
std_ccsm = 1.072079
std_ground = 1.2027843
std_ann_raw = 0.334979
std_ann_bc = 0.9740444

rmse_ccsm = 3.0686014
rmse_ann_raw = 2.2245069
rmse_ann_bc = 2.0080667



Results

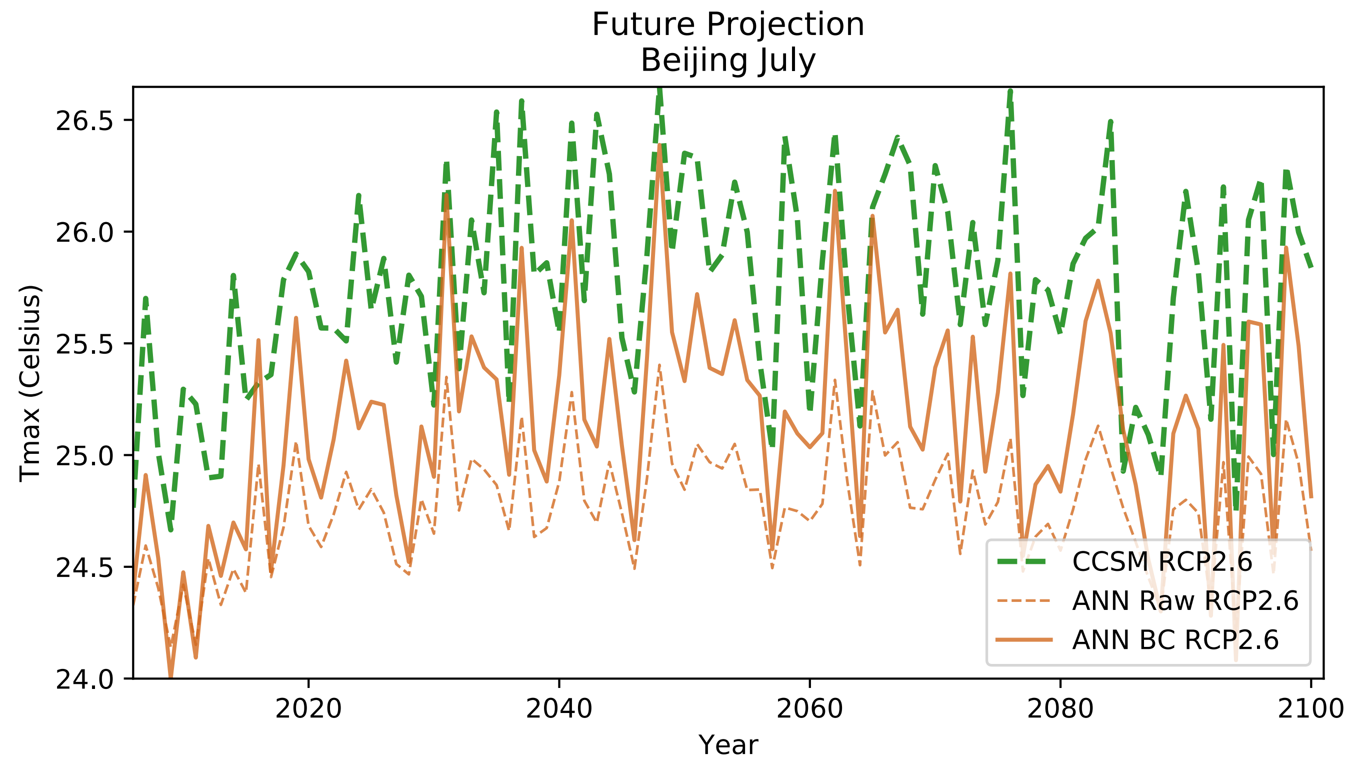
Beijing Future Projection



Results

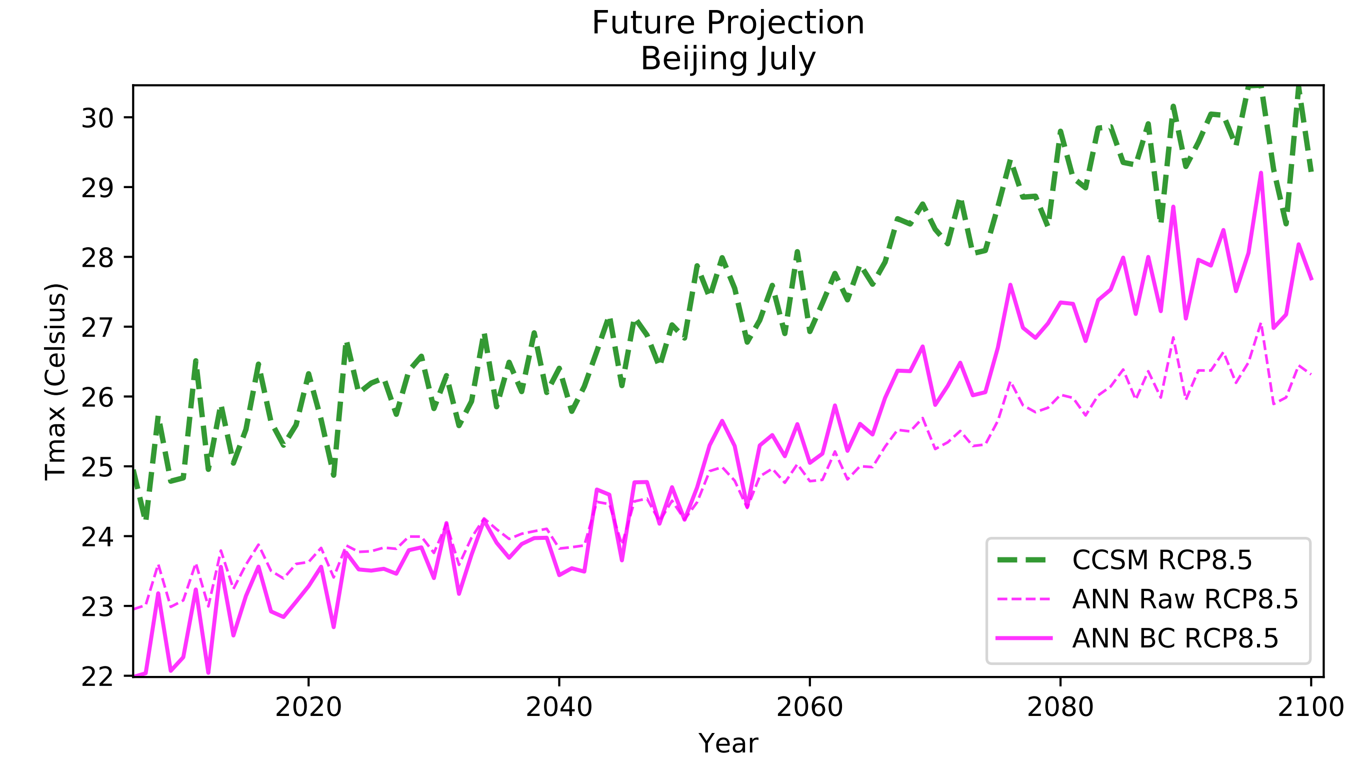
China Future Projection

Tmax




```
mean_ccsm_rcp26 =  25.749495
mean_ann_raw_rcp26 =  24.763618
mean_ann_bc_rcp26 =  25.142452

std_ccsm_rcp26 =  0.4883429
std_ann_raw_rcp26 =  0.26531196
std_ann_bc_rcp26 =  0.488927
```




```
mean_ccsm_rcp85 =  27.413929
mean_ann_raw_rcp85 =  24.774569
mean_ann_bc_rcp85 =  25.154882

std_ccsm_rcp85 =  1.5869676
std_ann_raw_rcp85 =  1.0651563
std_ann_bc_rcp85 =  1.8366457
```

谢谢

附录

Beijing Tmax

Future Projection

```
mean_ccsm_rcp26 =  29.605999          std_ccsm_rcp26 =  1.5404105
mean_ann_raw_rcp26 =  32.9098         std_ann_raw_rcp26 =  0.6658796
mean_ann_bc_rcp26 =  32.997334        std_ann_bc_rcp26 =  1.999466

mean_ccsm_rcp45 =  30.11801           std_ccsm_rcp45 =  1.8410892
mean_ann_raw_rcp45 =  32.867393       std_ann_raw_rcp45 =  0.70861655
mean_ann_bc_rcp45 =  32.827602        std_ann_bc_rcp45 =  2.1277914

mean_ccsm_rcp60 =  30.518694          std_ccsm_rcp60 =  1.8874353
mean_ann_raw_rcp60 =  32.95568        std_ann_raw_rcp60 =  0.81816405
mean_ann_bc_rcp60 =  32.827602        std_ann_bc_rcp60 =  2.1277914

mean_ccsm_rcp85 =  31.111483          std_ccsm_rcp85 =  2.4514613
mean_ann_raw_rcp85 =  32.9538         std_ann_raw_rcp85 =  0.9290221
mean_ann_bc_rcp85 =  33.173454        std_ann_bc_rcp85 =  2.7896135
```

附录

Reference：

1. Projecting extreme heat-related mortality in Europe under climate change, Chun Kit Ho, April 2010

2. Calibration and bias correction of climate projections for crop modelling: An idealised case study over Europe

（https://www.sciencedirect.com/science/article/pii/S0168192312001372）