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Uncertainty Estimation of Hydrological Impacts of Bias-Corrected CMIP5 Climate Change Projections

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1. Introduction

- Climate change scenarios in future, especially daily rainfall, are critically important for water resources management and planning, agriculture and water-users.

- It is clear that assessment of impact of climate change on hydrology and water resources suffers from large uncertainties. These can be divided into:

(1) Uncertainty related to different **GCM mdels**,

(2) uncertainty related to different **representative concentration pathways** (RCPs),

(3) uncertainty to **downscaling methods**

(4) uncertainty of **hydrological models**.

- Few researches focused on uncertainty of using different **observed datasets** as historical data to bias-correct GCM or RegCM data.

1. Introduction

➢ Objectives

This research mainly focused on the following issues:

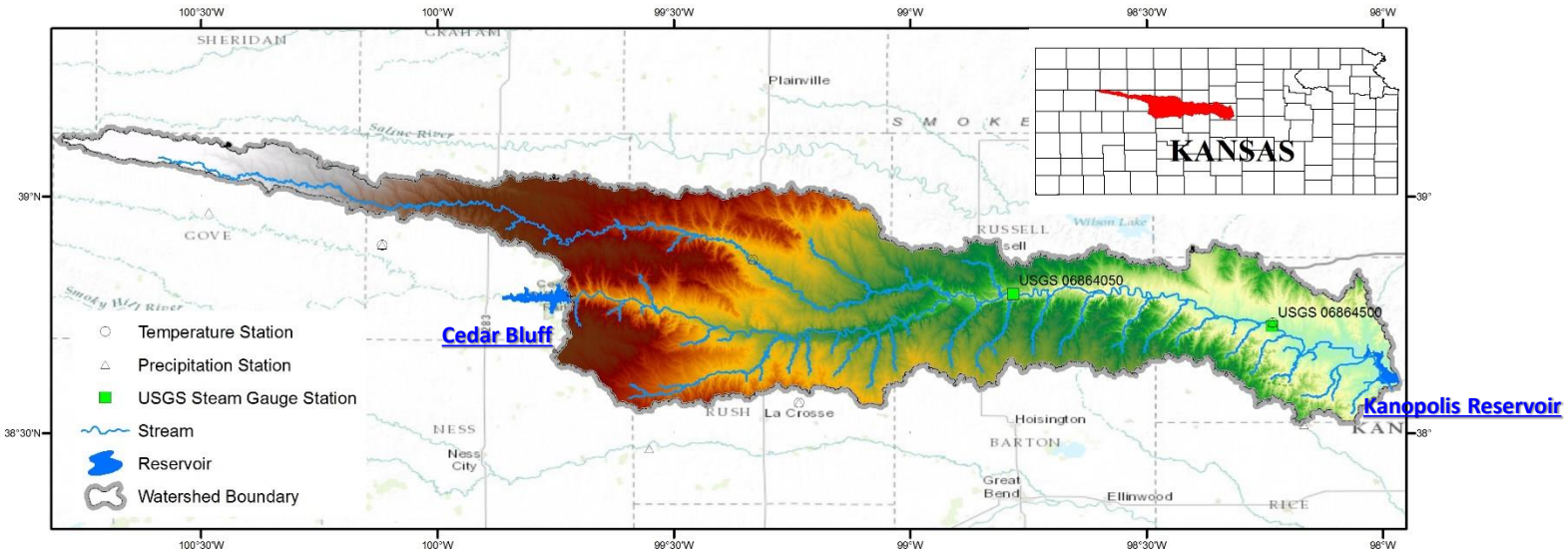
(1) Assessing changes of GCM climate data with and without bias correction

(2) Analyzing the uncertainties of bias corrections with different observed datasets

(3) Comparing hydrological impacts under different bias-corrected future climate scenarios using SWAT model.

2. Materials and Methods

2.1 Study area



- Middle Smoky Hill River (SHR) watershed, a 6,310.42 km^2 (1,559,338 ac) sub-watershed of the Arkansas Red Basin, is **located** within 11 counties in western Kansas.
- The **major tributaries** of SHR and water released from Cedar Bluff Reservoir together feed into the Kanopolis Reservoir
- Primary **land use types** are cropland (47%), pasture (47%), and 6% other land use (forest, urban, water, wetland, etc.).
- Highly variable **precipitation** from about 381 mm in the west to 635 mm in the east.
- Averaged **elevation**: 617 m (from 445 m to 925 m)

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2.2 Weather datasets and SWAT model

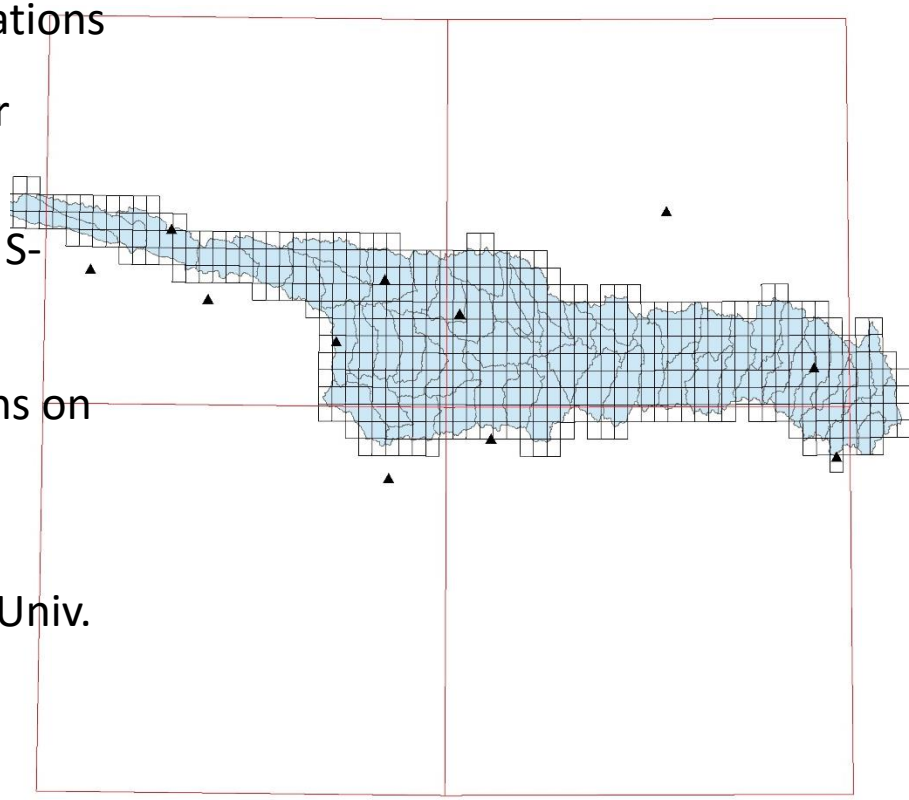
- **Weather datasets**

CMIP 5: RCP 8.5 emission of NCAR CCSM4 model (**2000s**: 1994-2005; **2050s**: 2045-2056; **2100s**: 2089-2100)
National Center for Atmospheric Research, USA

NCDC: NOAA National Climatic Data Center(1994-2005)
Network of point land-based stations

NEXRAD: Next Generation Weather Radar (1994-2005) - Stage III
Network of 160 high-resolution S-band Doppler weather radars

PRISM: Parameter–elevation Regressions on Independent Slopes Model (1994-2005)
Climate Group @ Oregon State Univ.
Simulated and calibrated on observed data



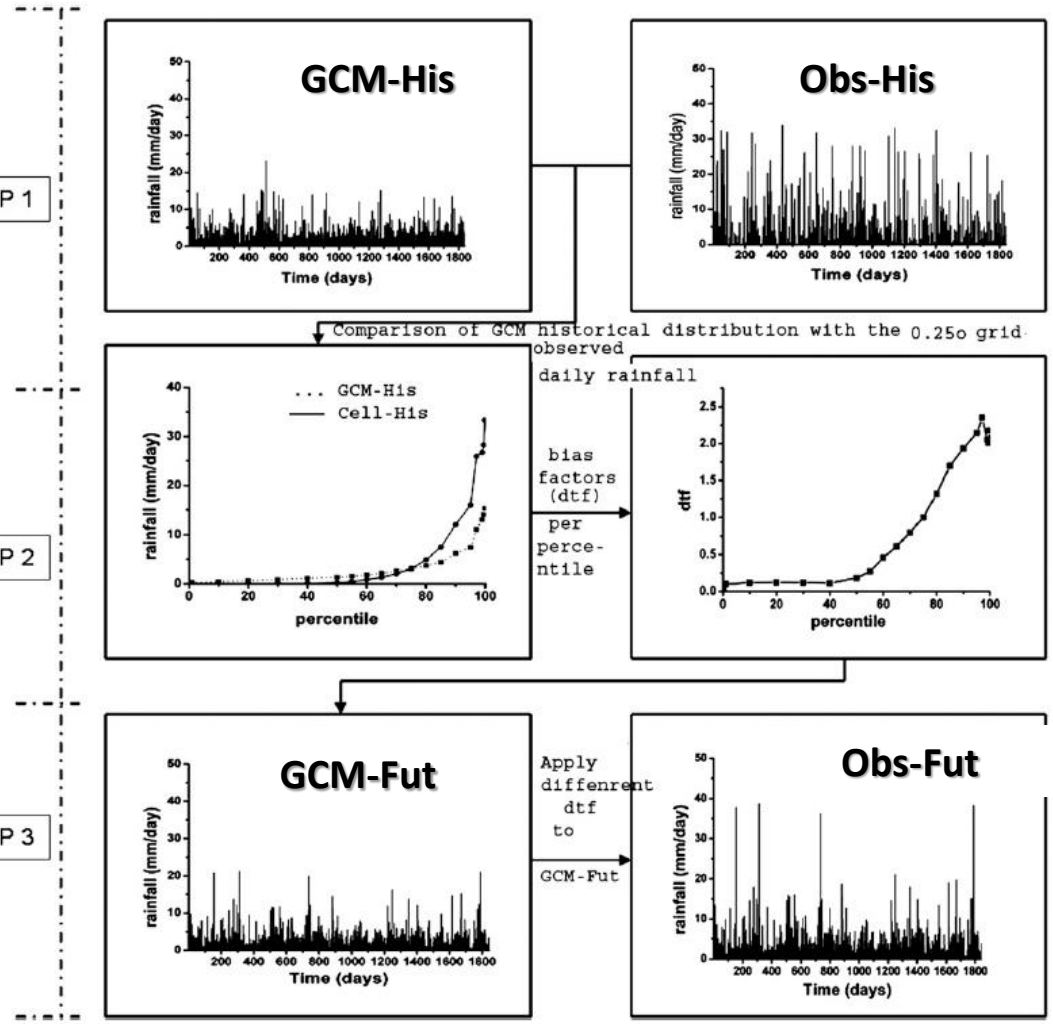
➢ Weather dataset processing

A distribution mapping technique:

- observed and GCM historical daily rainfalls **<u>at the different rainfall ranks/percentiles</u>**.
- **Translate** the GCM future daily historical rainfall series to obtain a observed future daily rainfall series.

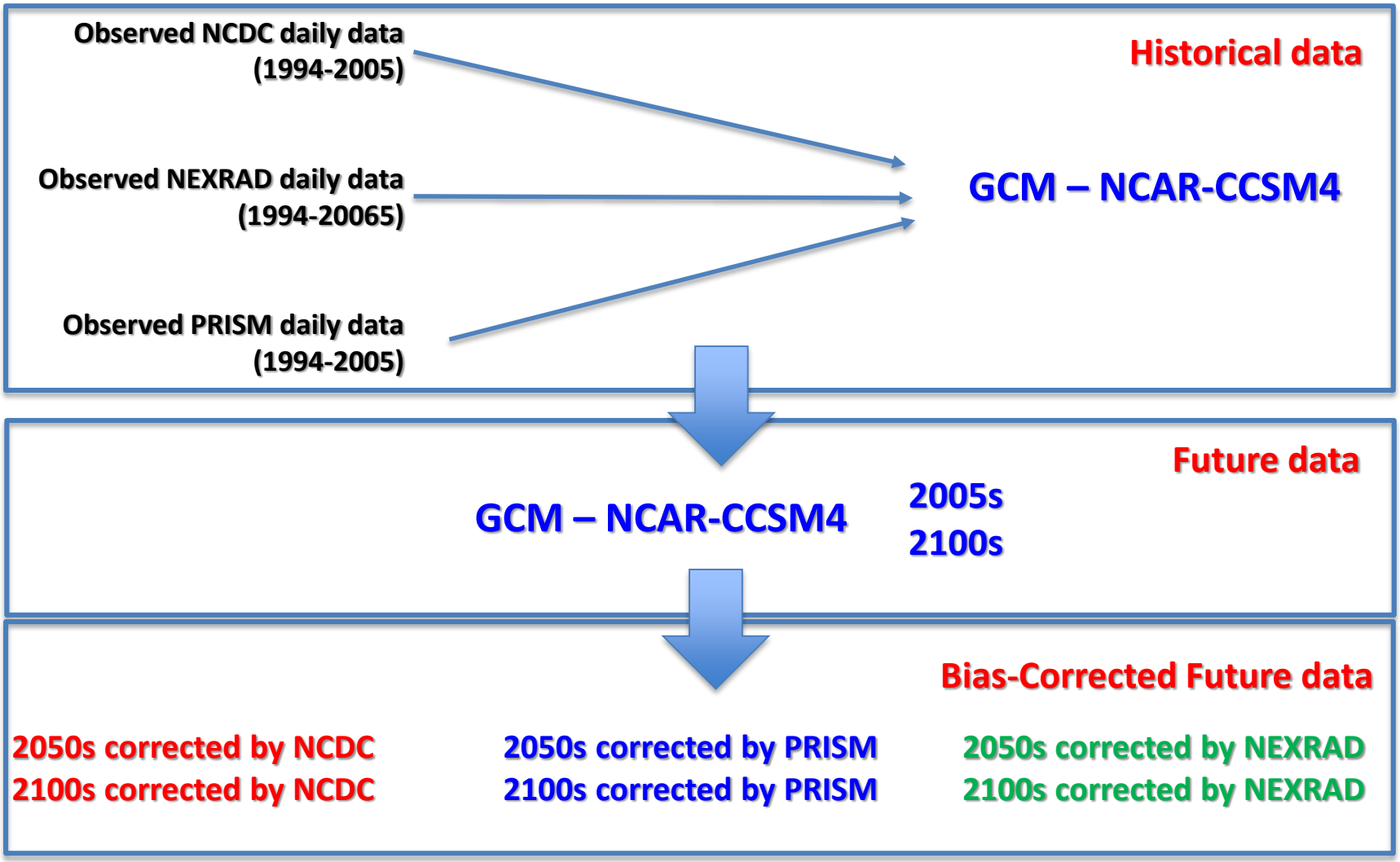
This approach keep observed daily rainfall sequence in GCM future daily rainfall sequence, but with GCM-scale values **<u>translated to finer gridcell/station scale</u>** values.

Bias Correction Method: Daily Translation

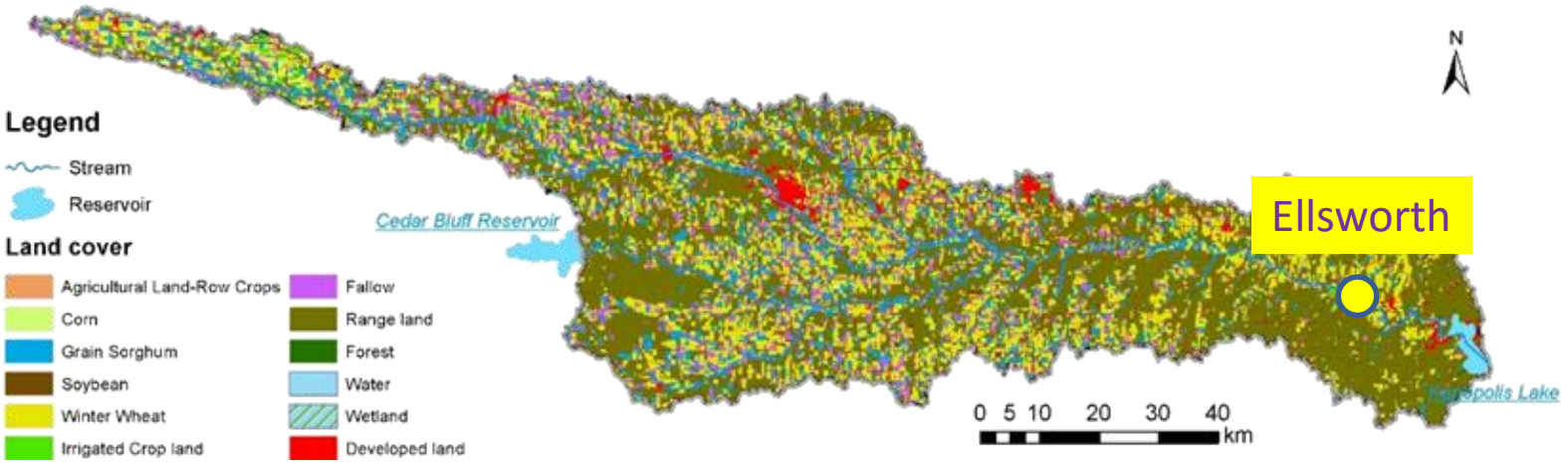


(Mapelasoka and Chiew, 2009)

➢ Weather dataset processing



- SWAT model for Smoky Hill River Watershed



- **10-m DEM, sub-field LULC by KBS, STATSGO soil, 16 crop rotations**
- **54 subbasins and 7179 HRUs**
- **Calibrated at 2 sites (Hays, Ellsworth) from 2008-2010**

Period	NSE	pBias	RSR	R^2
Calibration (2008-2010)	0.79	2.76	0.46	0.79
Validation (2005-2007)	0.84	17.55	0.40	0.86
Validation (2011-2012)	0.84	13.65	0.41	0.84

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3. Results

3.1 Climate Change Scenarios

- Compared with Bias-corrected data: GCM underestimated precipitation and tasmin, and overestimated tasmax.

Scenario	Annual change in precipitation (%)			
	Original	Bias-corrected data		
	GCM	NCDC	PRISM	NEXRAD
2050s	0.21	2.68	3.13	2.48
2100s	0.32	2.95	3.36	2.70

Scenario	Annual change in tasmax (%)		
	GCM	NCDC	PRISM
2050s	1.63	-1.08	2.16
2100s	3.97	1.26	8.30

Scenario	Annual change in tasmin (%)		
	GCM	NCDC	PRISM
2050s	1.57	-0.86	1.17
2100s	3.55	1.12	3.18

- All data including corrected data showed a increasing trend in precipitation at time series.
- Precipitation:
  The largest increase -> PRISM
  The lowest increase -> NEXRAD
- Temperature: PRISM predicted the higher value than NCDC.

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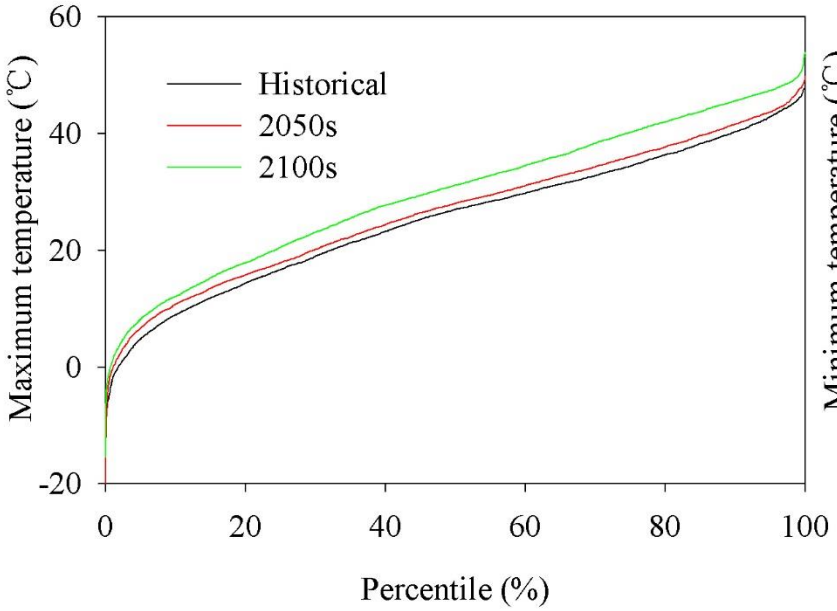
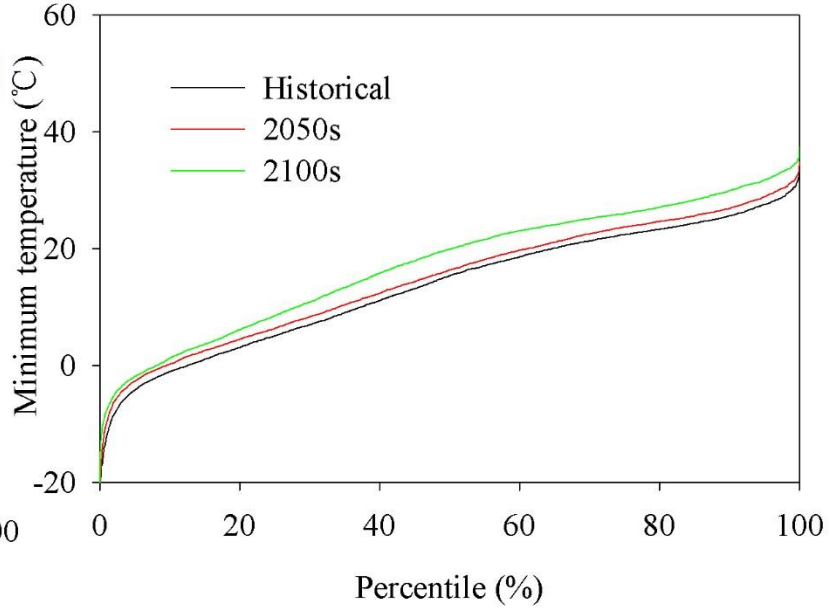
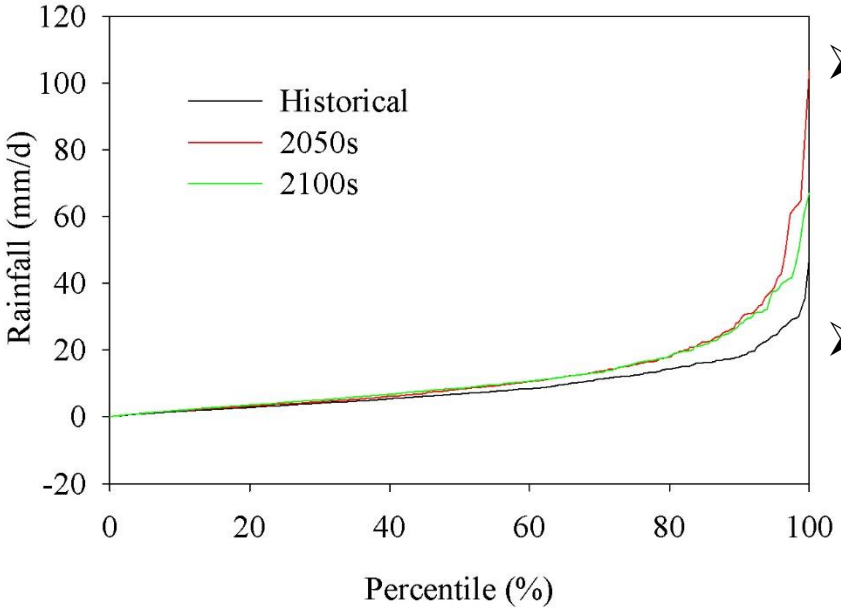
3.1 Climate Change Scenarios

Original data of GCM



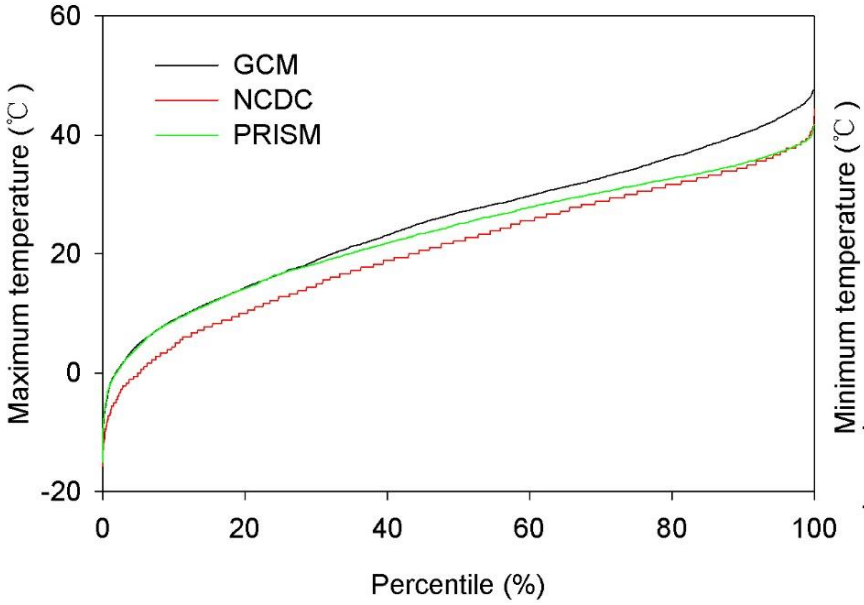


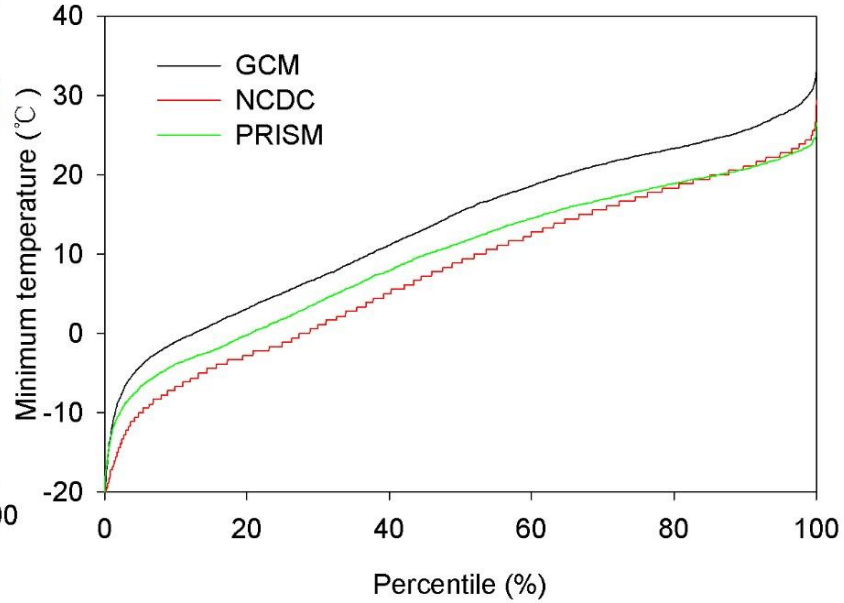


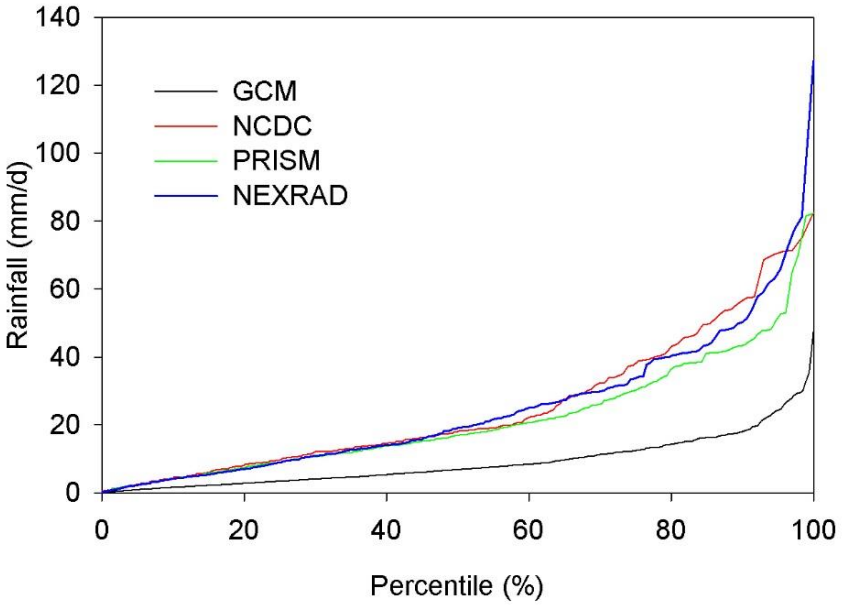
- Cumulative distributions of pcp, tasmax, tasmin showing that both maximum and minimum temperatures area increasing.
- Precipitation: frequency in big rainfall events will be higher in 2050s than in 2100s.

3.2 Uncertainty of Bias-corrected weather data

Historical Observed Data





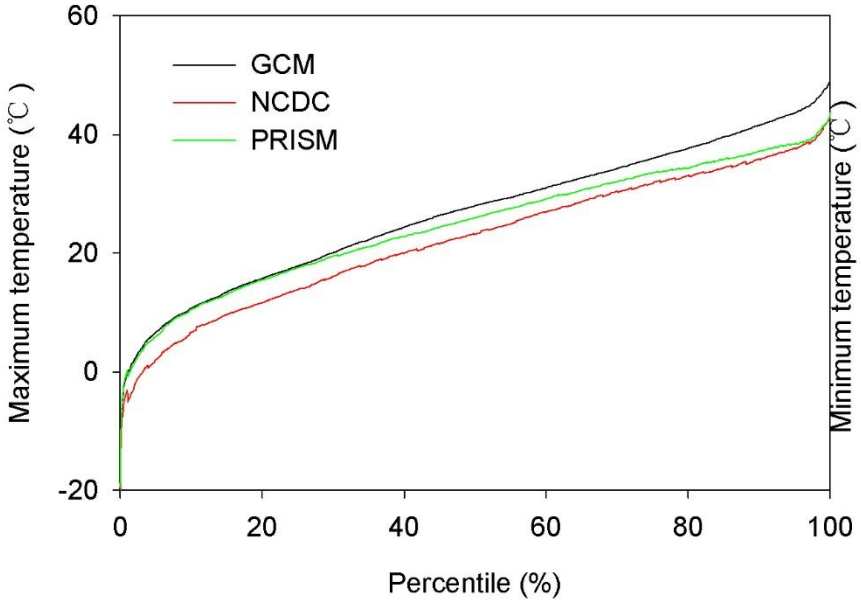


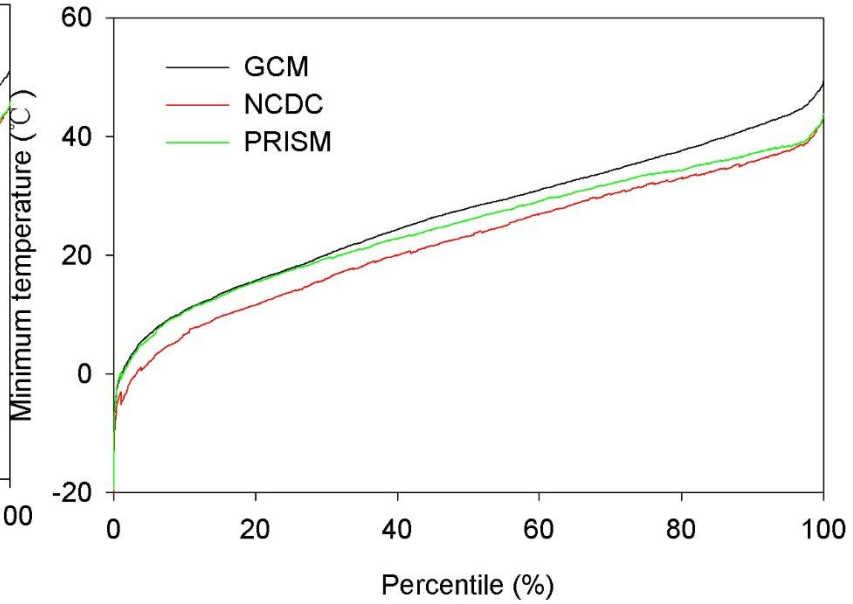
- PRSIM tasmax is more approaching GCM tasmax for lower max temperature events, while PRISM closed to NCDC at higher tasmax events.
- Precipitation: GCM is significantly lower than three observed datasets
- Big rainfall events:

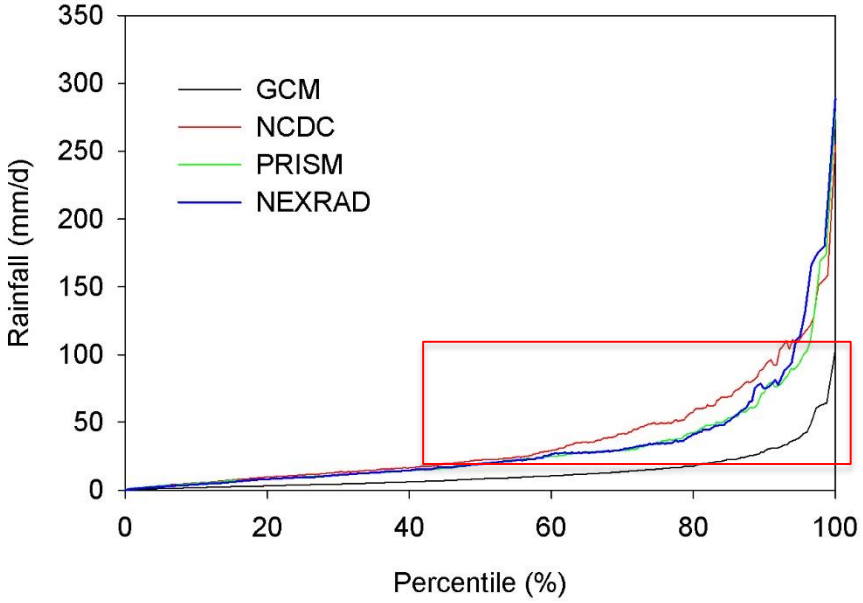
NCDC > NEXRAD > PRISM > GCM

3.2 Uncertainty of Bias-corrected weather data

2050s



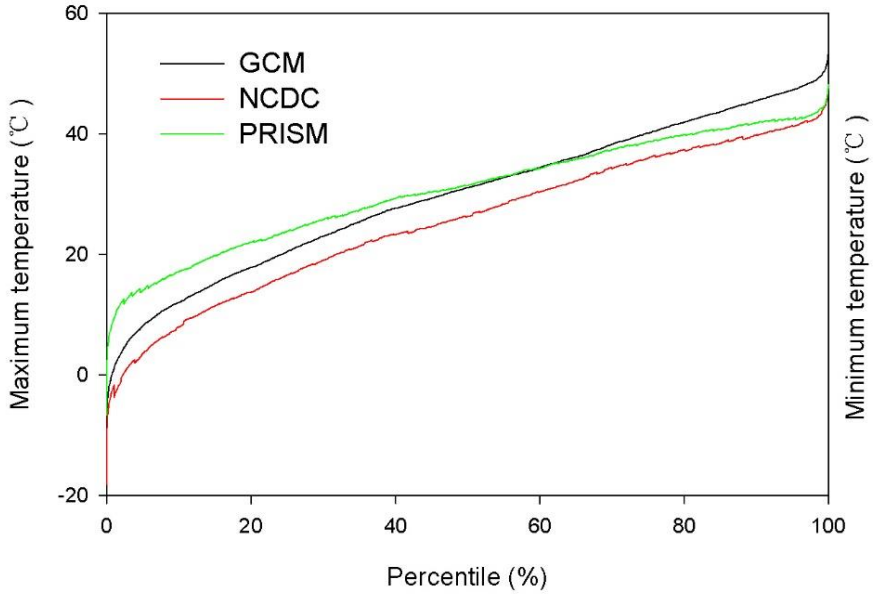


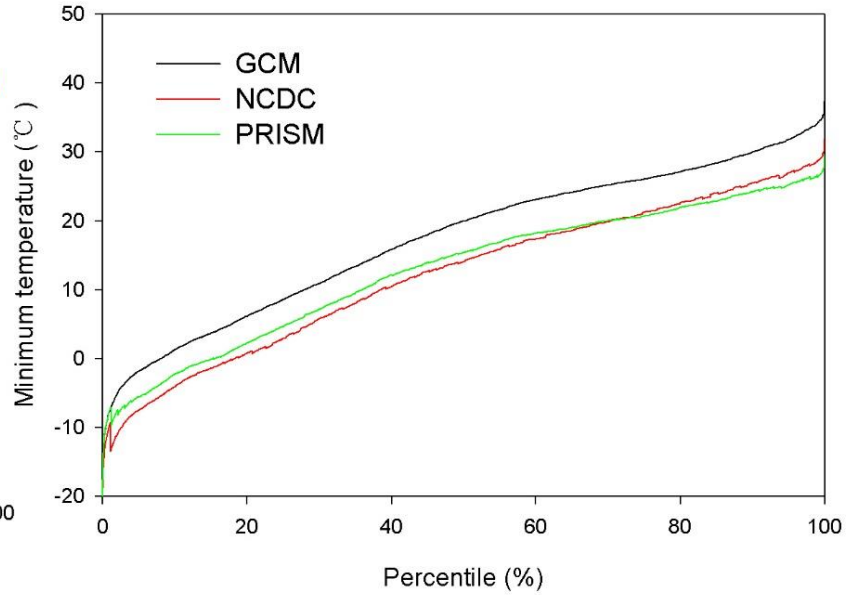


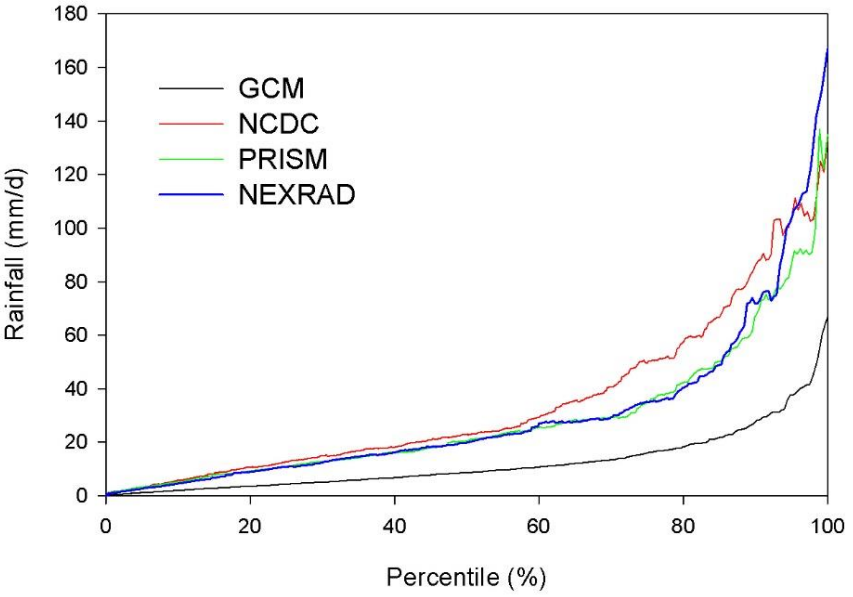
- PRSIM corrected the GCM differently for various tasmaxs, not like the NCDC.
- GCM Precipitation corrected by NCDC has higher frequency at moderate rains.
- The data corrected by NEXRAD and PRISM predicted higher frequency in extreme rainfall events than NCDC did.

3.2 Uncertainty of Bias-corrected weather data

2100s



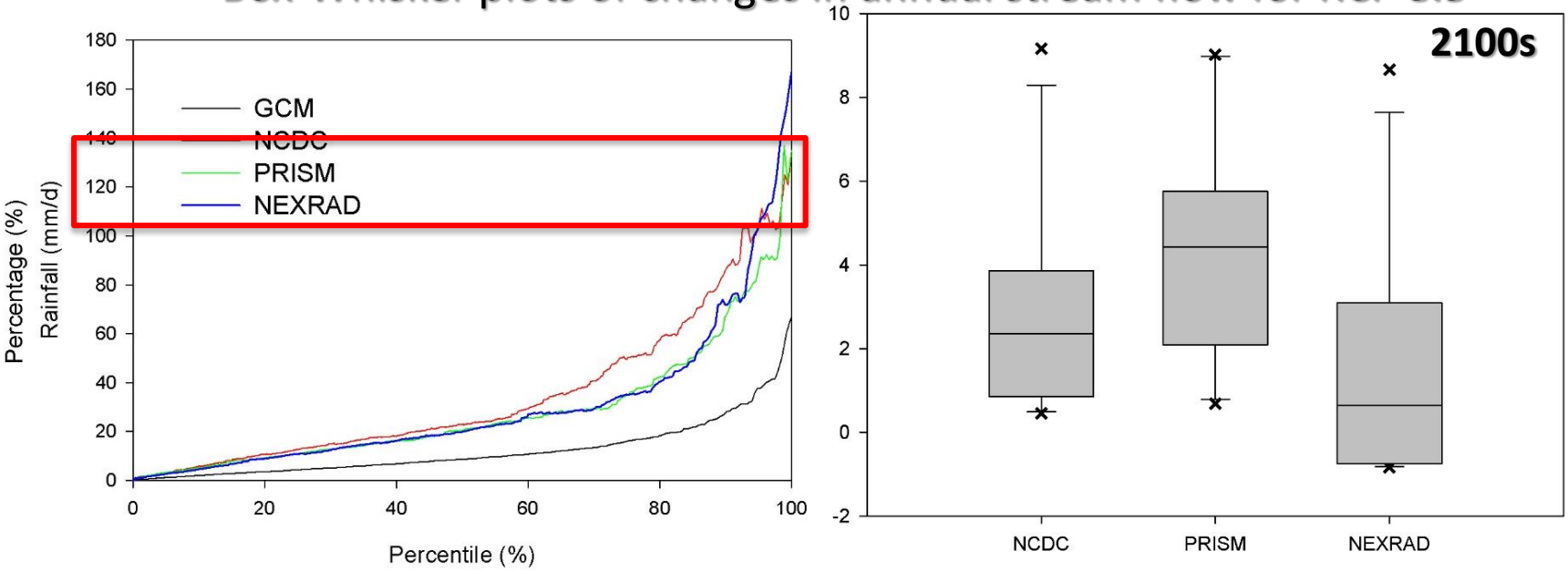




- More conspicuous phenomenon was observed in the 2100s.

3.3 Impacts of climate change on stream flow

Box-Whisker plots of changes in annual stream flow for RCP 8.5



- SWAT using **PRISM** corrected data predicted the **highest change** in stream flow in **2050s and 2100s**, compared with other two projections.
- The lower stream flow in **NCDC** relative to in PRISM doesn't agreed with higher precipitation and lower temperature in NCDC, other factors are needed to be recognized in the future.
- **NEXRAD** estimated the higher frequency of **extremely big precipitate events** with **lowest stream flow,** and PRISM displayed the highest stream flow with big events.
- The reason may be that too many **high precipitation** events happened **in summer,** not helping to improve annual mean flow.

4. Conclusions and Further Works

- There is a significant change for GCM climate data when using bias corrections with different observed datasets at time series.
- Bias corrections with different observed datasets don't have a consistent effect on temperature or precipitation.
- It should be noted uncertainty of hydrological impacts under different bias-corrected future climate scenarios.

- More models and emission scenarios and more bias correction methods will be involved in the future.

Thanks for your attentions!

- **Acknowledgements:**

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