NSBC: Deep learning for non-stationary bias correcting of future climate projection

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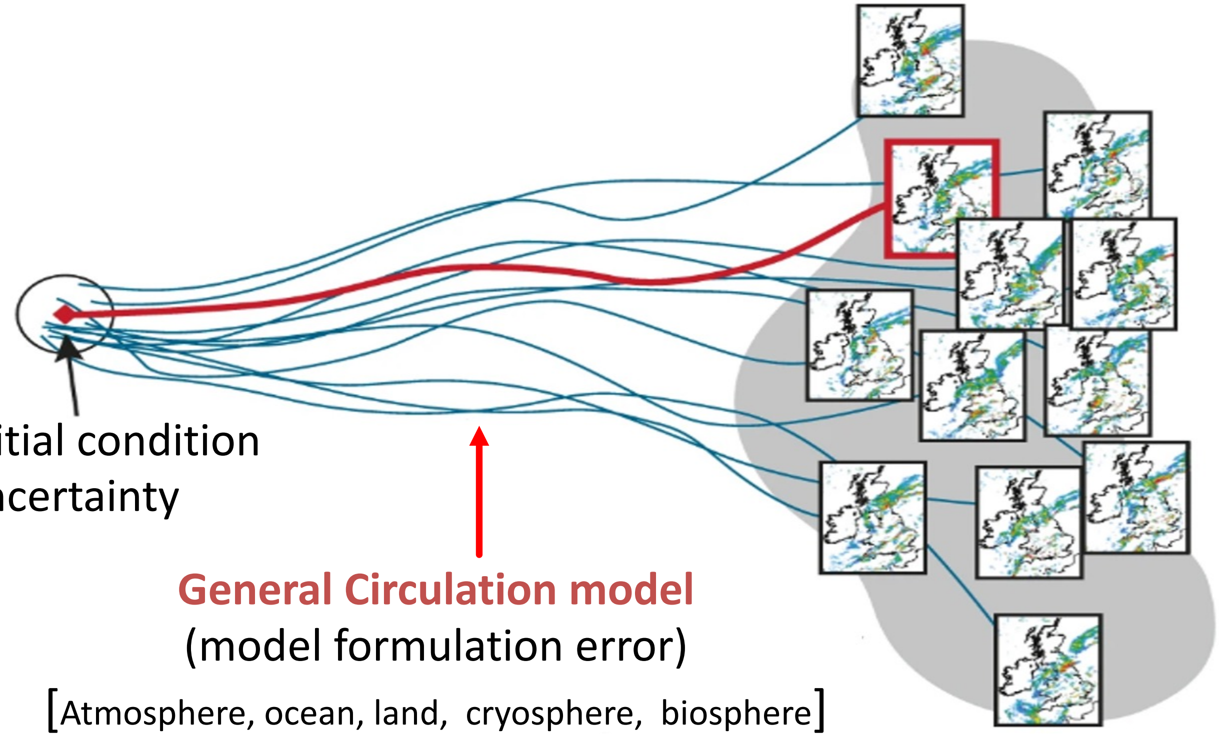
Global Climate Models (GCMs) have bias



Initial condition uncertainty

General Circulation model
(model formulation error)
[Atmosphere, ocean, land, cryosphere, biosphere]

Insufficient sampling of forecast spread

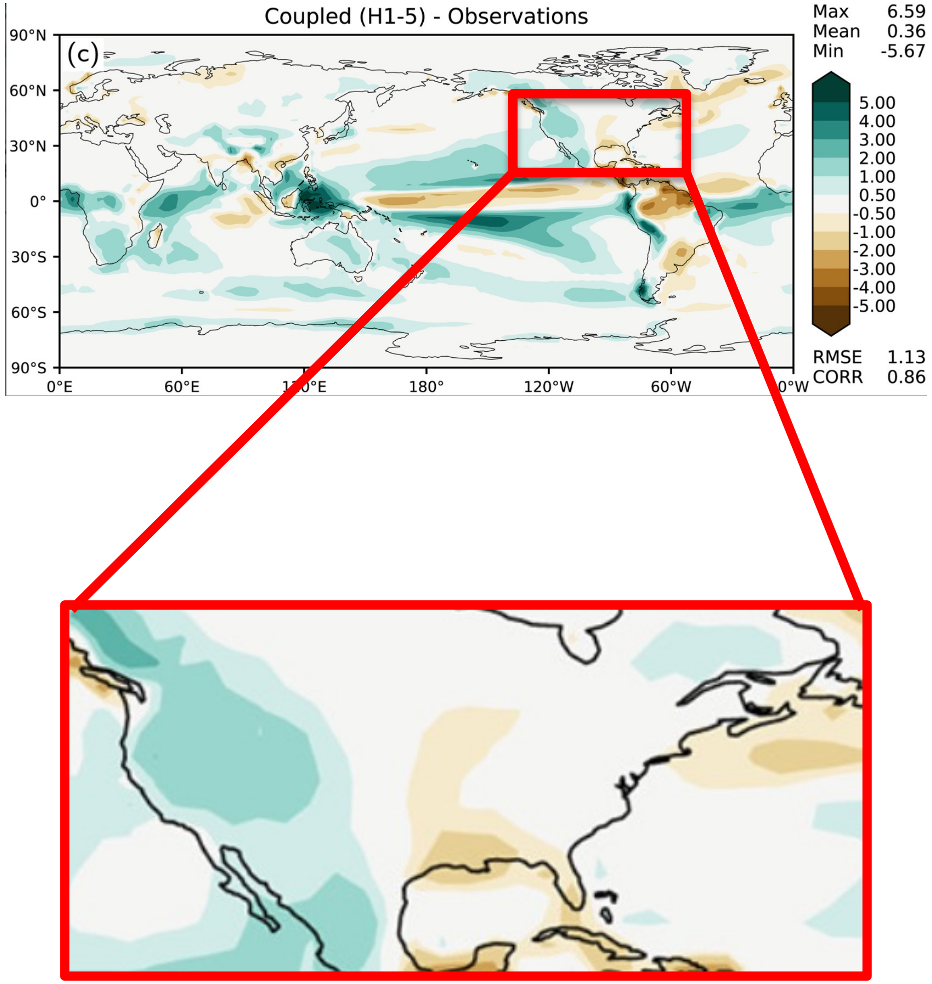
Bauer et al., 2015 (Nature)

- GCM biases: due to the parameterization and misrepresentation of physical processes, and coarse grid resolution.

- Reduce and correct the biases of GCM outputs through post-processing and statistical analysis.

E3SM (Energy Exascale Earth System Model) precipitation Bias

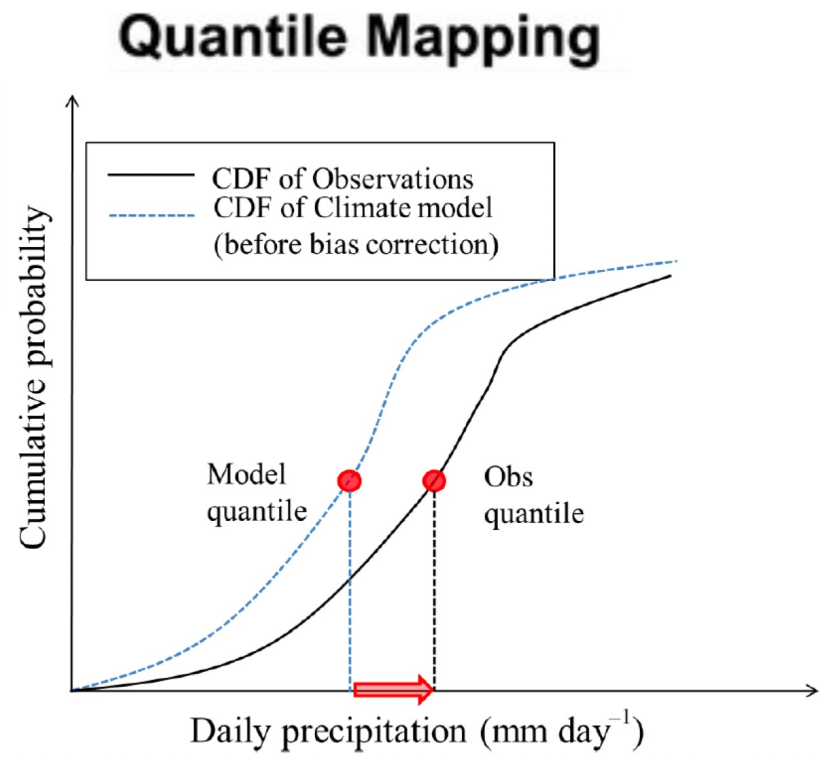
- too frequent, too weak
- Over predicts precipitation occurrence for rainfall rates less than 15mm/day and under predicts the occurrence of large rain events.
- Within CONUS, under-estimation of annual precipitation at the Gulf Coast and over-estimation at the West-Coast.



- AI-3 = 3 AMIP
- H1-5=five ensemble his

Golaz et al (2019)

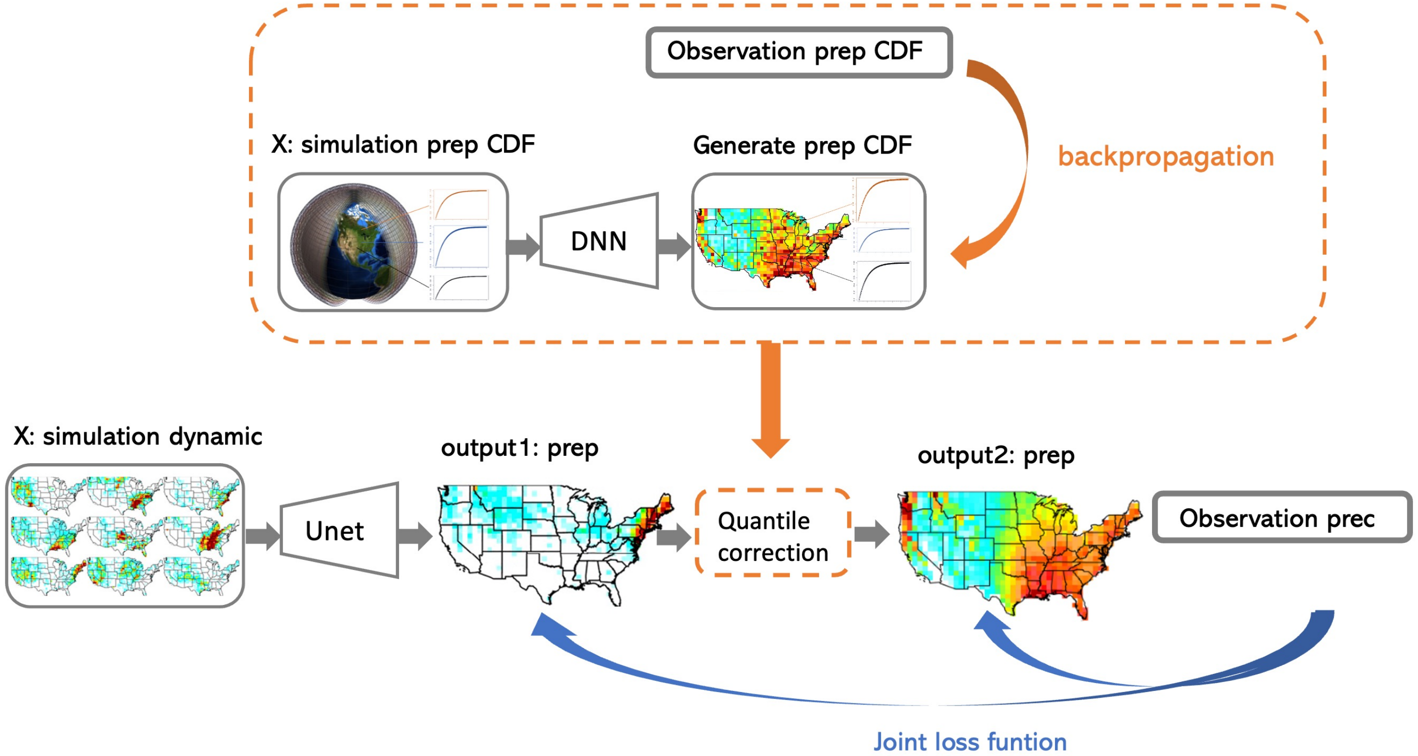
Current bias correction methods ——Quantile mapping

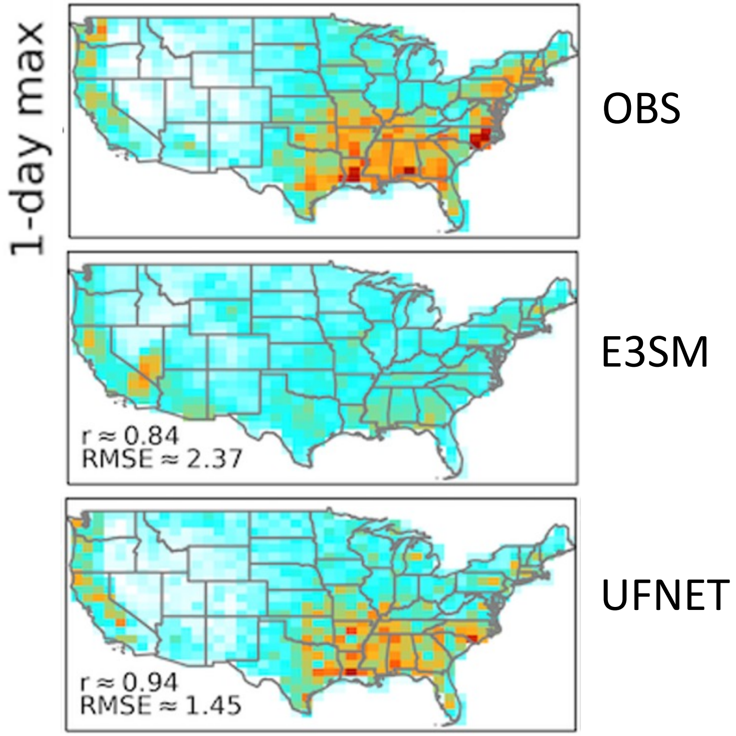


- Post-processing bias correction method to correct systematic distributional biases within the climate model.
- maps the 1-D CDF of the simulated precipitation to that of the observed precipitation for a given historical period.
- Hard to improve the spatial structure.
- Can lead to unrealistic distributions.
- Accuracy deteriorates as historical and future simulation periods diverge.

Source: Kim, K. B., Kwon, H. H., & Han, D. (2016).

Deep learning based bias correction—— UFNet





- UFNet combines two different deep learning architectures to effectively simulate highly realistic precipitation fields.
- UFNet bias corrects the spatial distribution of precipitation and represents extreme precipitation well.

Summary: current bias correction methods

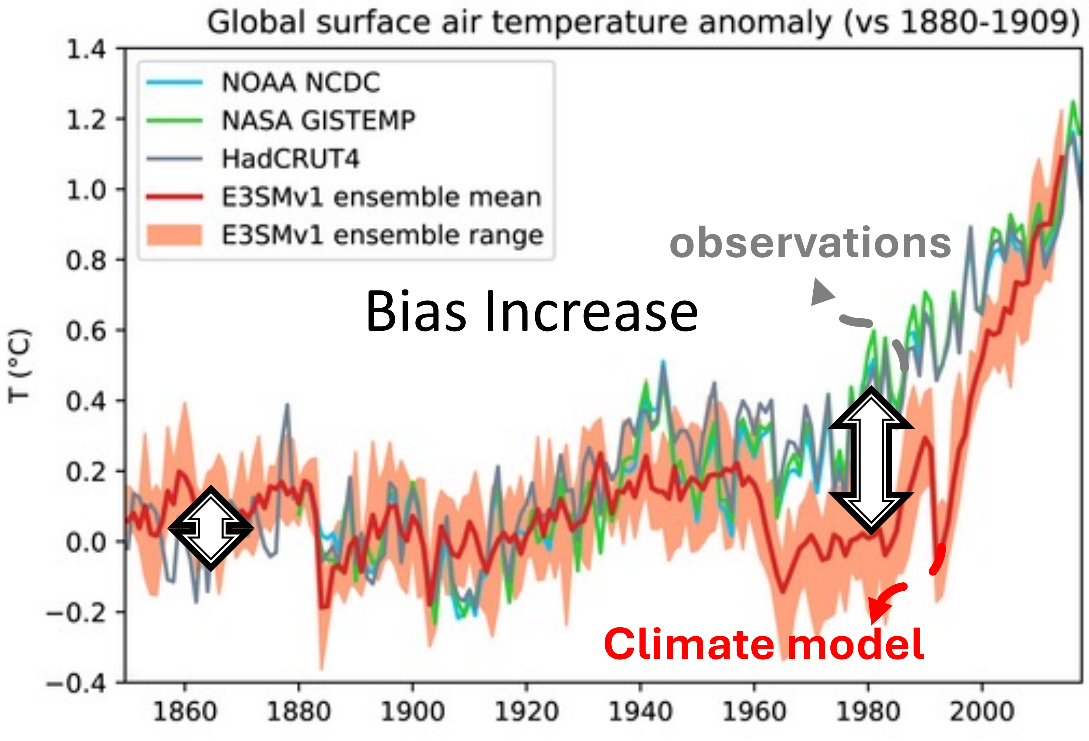
Basic thinking:

Train the bias correction based on historical period, but apply it on the current and future climate.

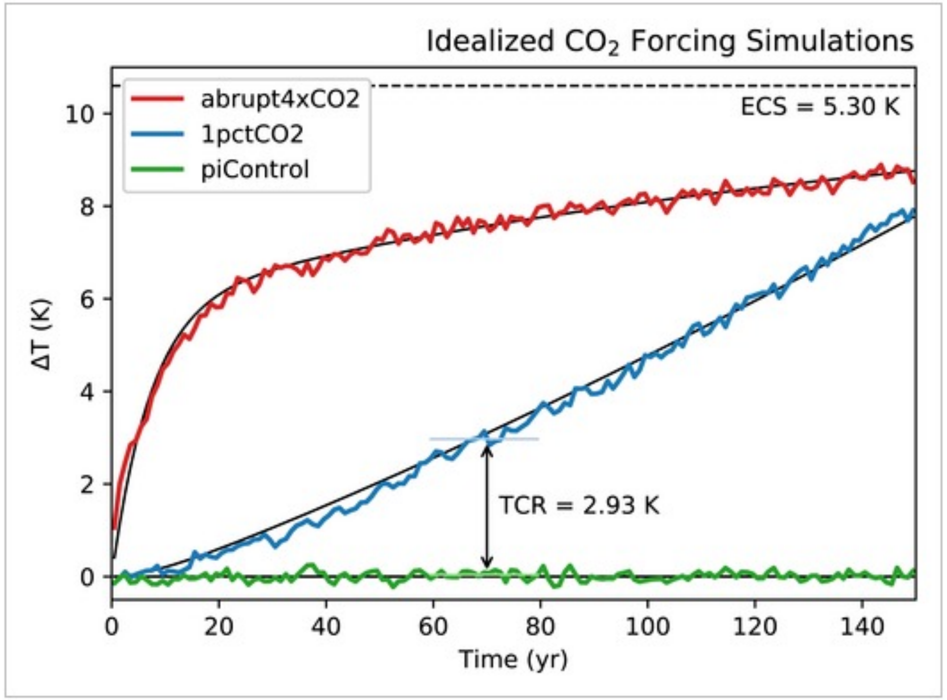
Assumption: stationarity of the bias from historical and future.

Not true

E3SM temperature bias changes



Bias increase from historical and current period.



The sensitivity of Climate model to CO2 concentration is complex.

Golaz et al (2019)

Challenge

1. How to capture the bias changes in the future and correct it?

   Develop a deep learning based bias correction framework, which can predict the changes of bias in the future.

2. How to evaluate the performance of the bias correction model in the future?

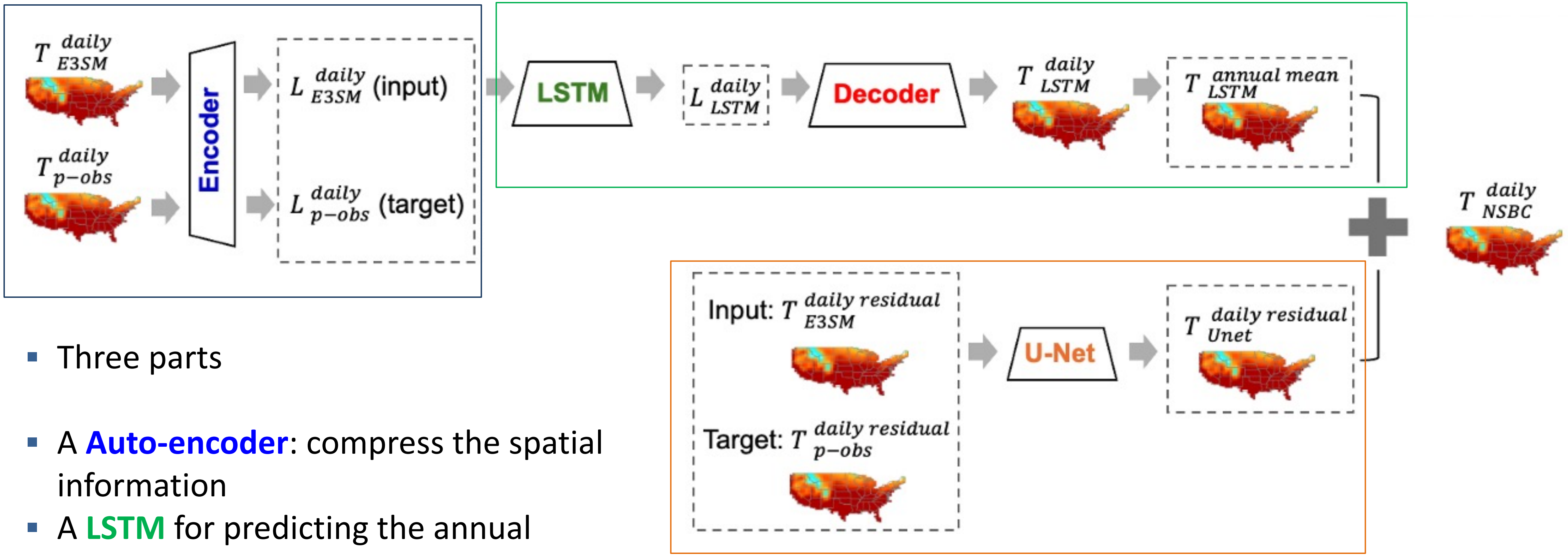
   pseudo observation : GFDL

   - High performance; large difference with E3SM temperature; long time period (1850-2099)

Data and Method

- Input feature: 2m temperature from E3SM
- pseudo observation : 2m temperature from GFDL
- Resolution: 1 degree, daily
- Training period: 1950-2021
- Test period : 2022-2099
- Baseline: EDCDFm bias correction method

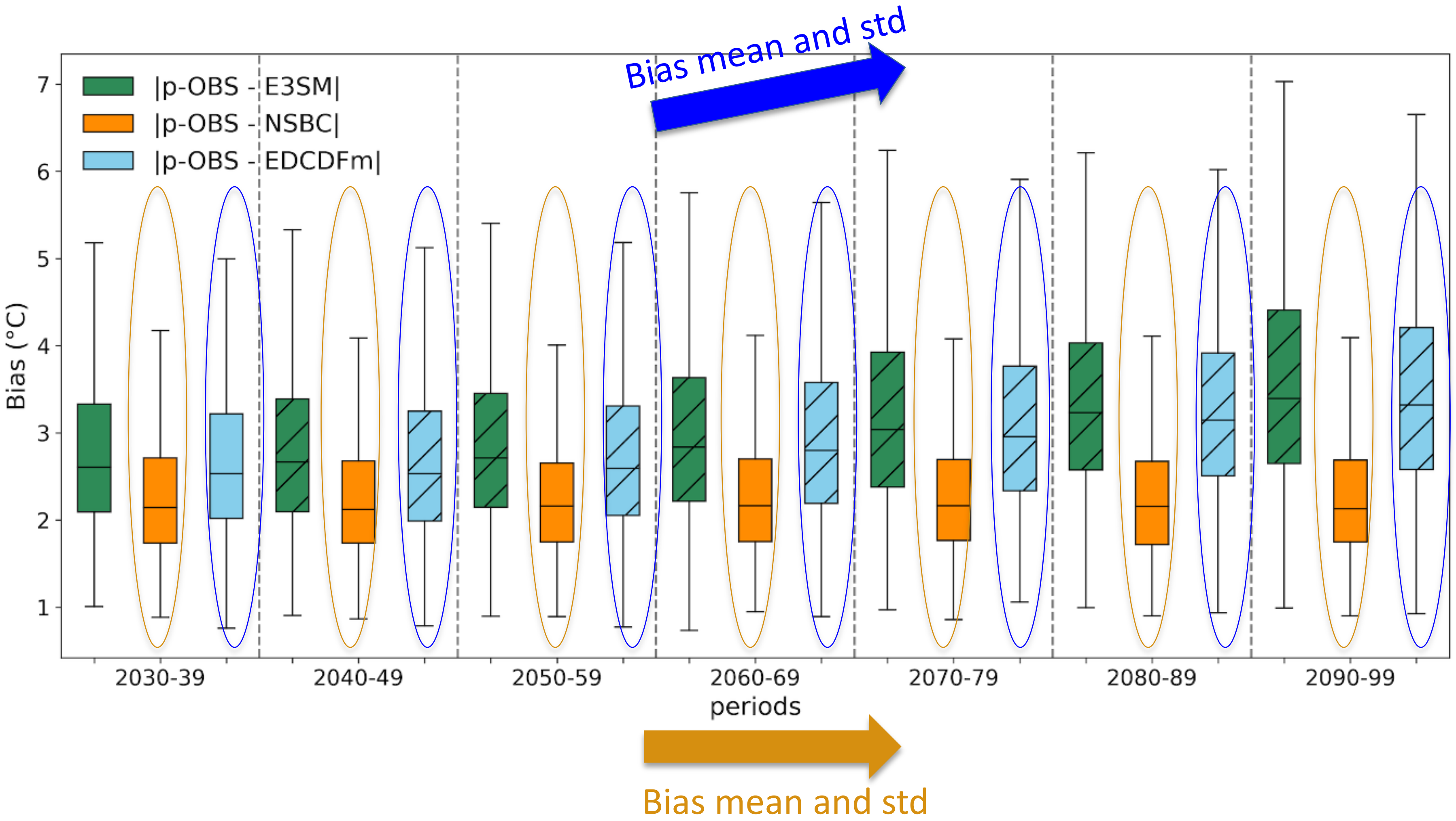
NSBC structure



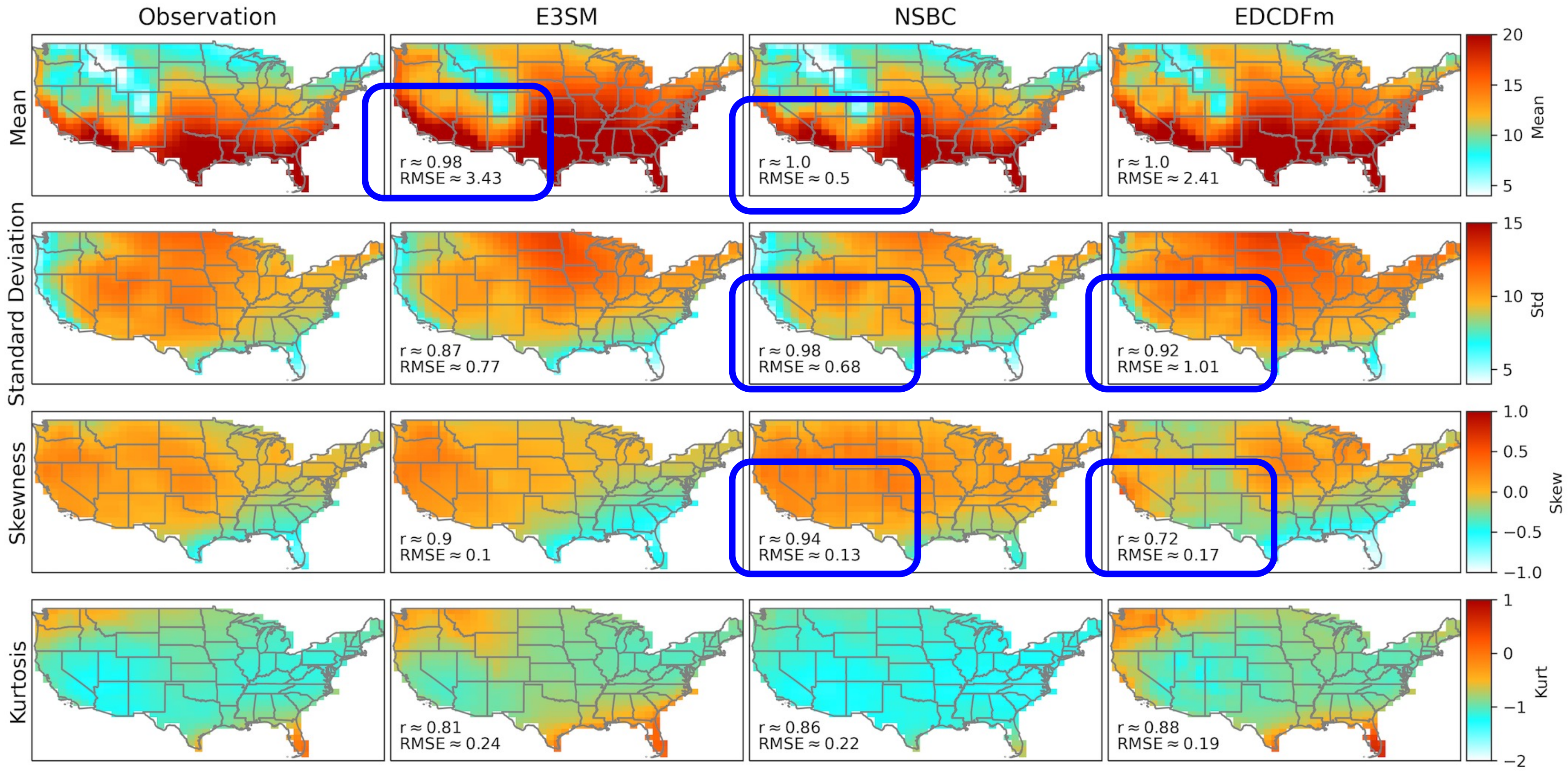
- Three parts

- A **Auto-encoder**: compress the spatial information
- A **LSTM** for predicting the annual temperature mean
- A **U-Net** for capture the daily residual bias in temperature.

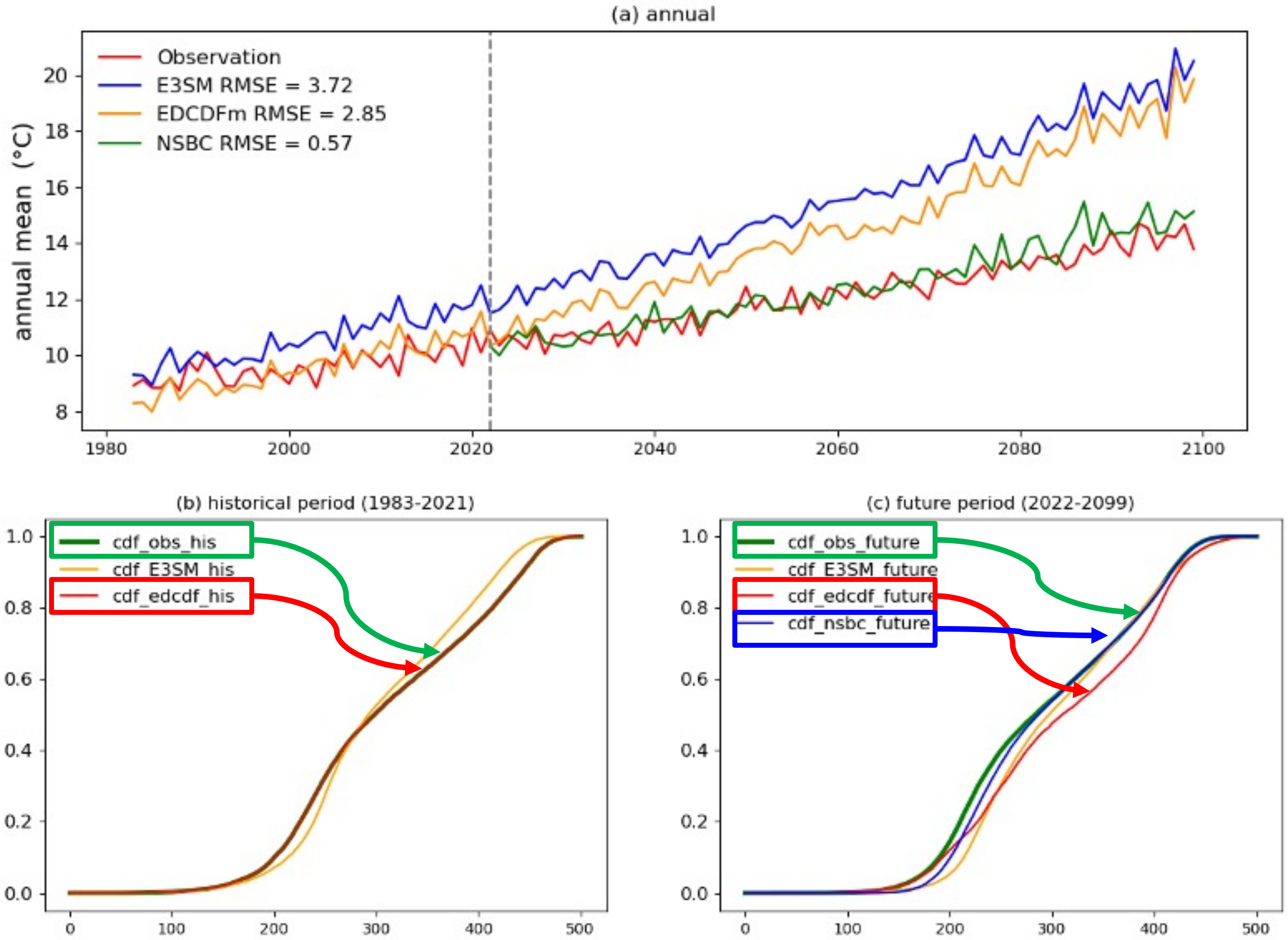
Evaluation: correct the mean and std of bias



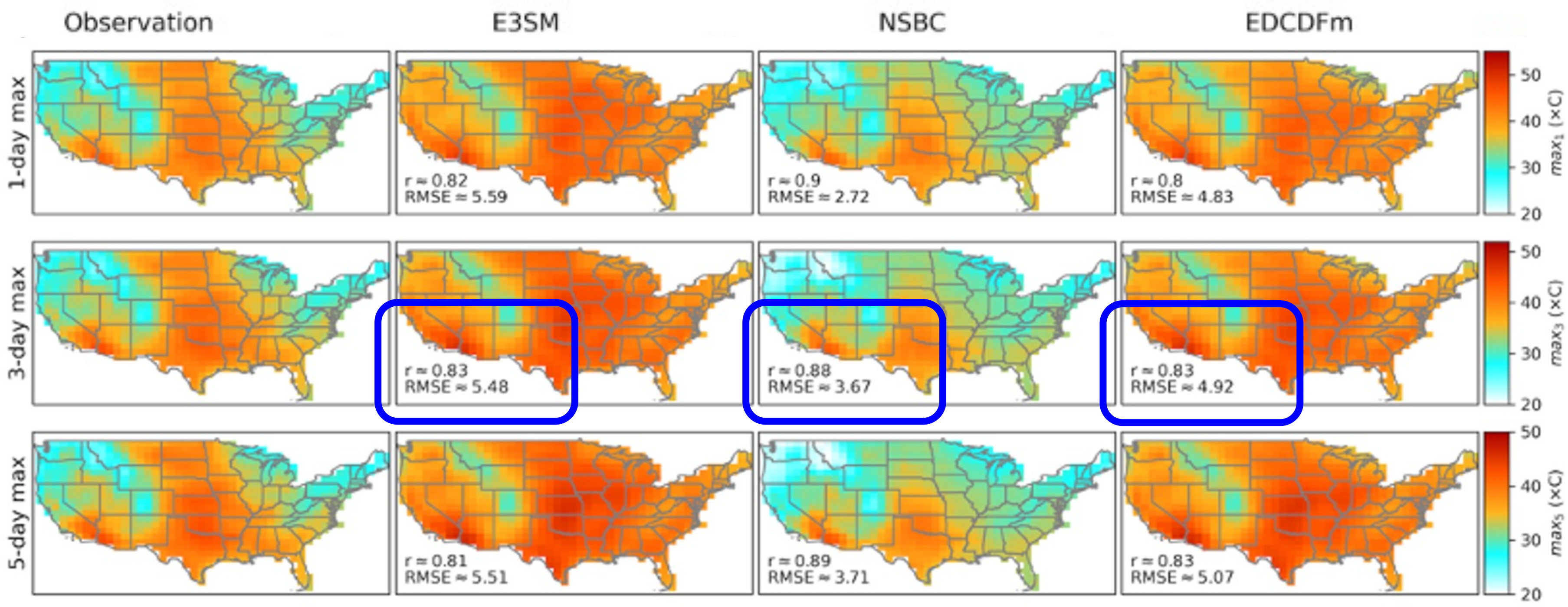
Evaluation: mean, std, skew, kurt



Evaluation: annual changes of temperature in the future



Evaluation: extremes



Summary

- NSBC combines three different deep learning architectures to effectively simulate highly realistic temperature fields, addressing the non-stationarity of biases - a significant challenge in bias correction for future climate projections.

- NSBC uses LSTM to extrapolate future mean temperature and captures future climate change features more accurately while preserving the spatial information's relevance.

- NSBC can make precise corrections to extreme temperature data, especially for heatwave events, which is crucial for studying extreme events and conducting risk assessments.

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