The Relationship Between Global Climate Model Biases and Future Projections of Temperature and Precipitation over the Central U.S.

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Research Questions

1. **What are the relationships between historical climate model biases and future climate projections in the Central US?**
2. **How do model biases introduce uncertainty into future climate projections?**

Data

Coupled Model Intercomparison Project Phase 6 (CMIP6)
- 40 models, based on data availability
- monthly precipitation
- monthly surface air temperature
  - **Historical:** 1990-2010
  - **Mid-century under SSP585:** 2040-2060

ECMWF Reanalysis v5 (ERA5)
- monthly 2m temperature (K)
- 0.25° x 0.25° grid

Global Precipitation Climatology Project (GPCP)
- monthly precipitation (mm/day)
- 2.5° x 2.5° grid

Methods

Regions:
- North Central US
- South Central US

Seasons:
- Spring (MAM)
- Summer (JJA)

Historical model bias:

$$P_{bias} = \frac{\left(P_{model,\,historical} - P_{observation,\,historical}\right)}{\left(P_{observation,\,historical}\right)}$$

$$T_{bias} = \left(T_{model,\,historical} - T_{observation,\,historical}\right)$$

Future (mid-century) projection:

$$P_{projection} = \frac{\left(P_{model,\,future} - P_{model,\,historical}\right)}{\left(P_{model,\,historical}\right)}$$

$$T_{projection} = \left(T_{model,\,future} - T_{model,\,historical}\right)$$

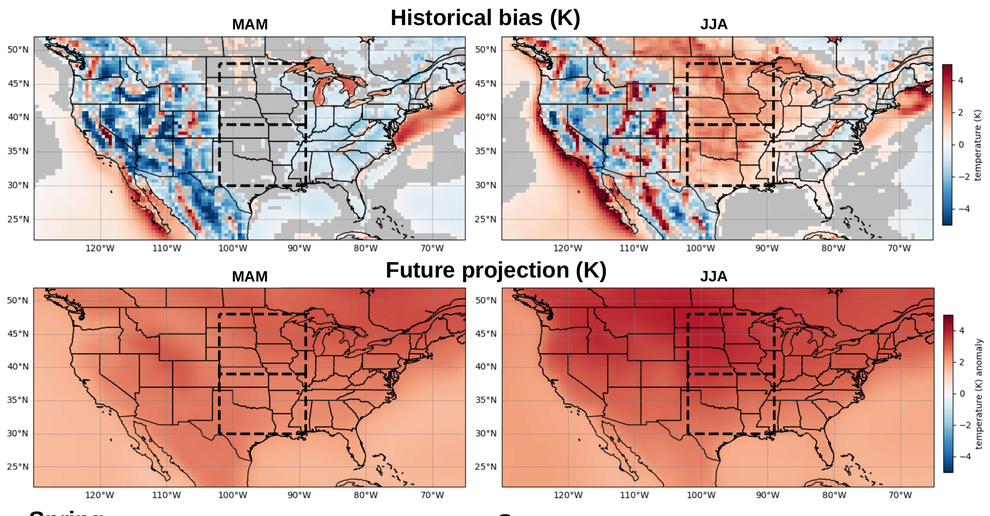
For ensemble averaging, all model data were regridded to a 360 latitude x 720 longitude grid.

A mean regional average for each model was tested for statistical significance using a two-tailed t-test.

Multi-model Ensemble Biases and Future Projections

*Grid points are shaded grey where <60% of models have the same sign of historical bias or future projected change.

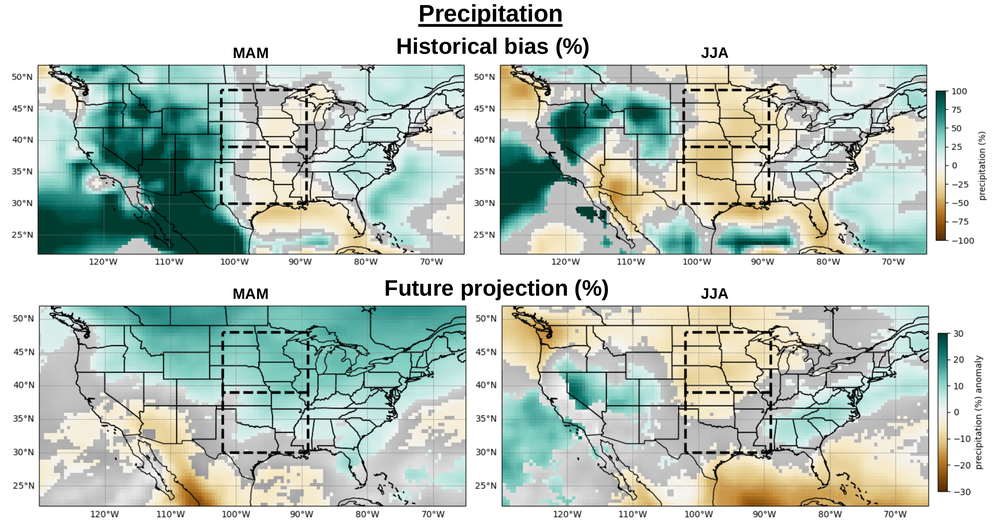
Surface air temperature



Spring
- No systematic temperature bias across models over the Central US
- Projected ensemble mean temperature warms by 2-3 K over the Central US

Summer
- Robust model agreement showing a warm bias over the Central US
- Projected ensemble mean temperature warms by 2-3.8 K over the Central US

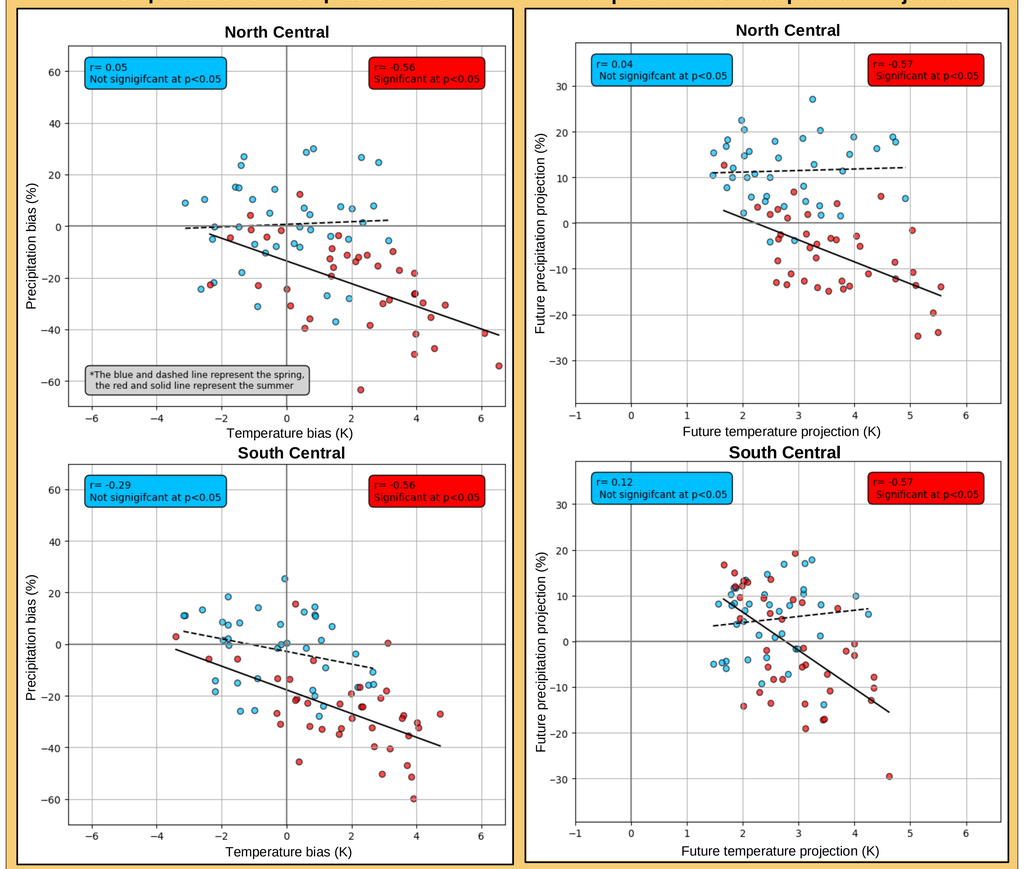
Precipitation



Spring
- Dry bias over parts of the Central US
- Future increases in precipitation over the North Central US

Summer
- Robust agreement showing a dry bias over the Central US
- Future decreases in precipitation over the North Central US

Relationships Between Seasonal Area-Averaged Biases and Projections



Historical biases

- CMIP6 models exhibit a statistically significant negative correlation between T and P biases in the summer over both the North and South Central US.
- The majority of models exhibit warm and dry biases during summer over the Central US.

Mid-century projections

- CMIP6 models exhibit a statistically significant negative correlation between future T and P in the summer over both the North and South Central US.
- Robust increase in T under SSP585.
- Wetter spring but drier summer in North Central US.

Conclusions

- The CMIP6 multi-model ensemble reveals a systematic relationship in which models with stronger warm biases have stronger dry biases during summer over the Central US in historical simulations (similar to past work, e.g., Zhang et al. 2018)
- CMIP6 models project stronger future drying for models with stronger future warming in summer over the Central US (supporting the conclusions of Cheruy et al. 2014).
- There was no significant relationship found between future precipitation projections and historical temperature biases (figures not shown).
- Results were insensitive to whether simulations in the same family of model were considered individually or averaged together (figures not shown).

References:

Cheruy, F., Dufresne, J. L., Hourdin, F., & Ducharne, A. (2014). Role of clouds and land-atmosphere coupling in midlatitude continental summer warm biases and climate change amplification in CMIP5 simulations. *Geophysical Research Letters*, **41**(18), 6493–6500. https://doi.org/10.1002/2014GL061145

Zhang, C., Xie, S., Klein, S. A., Ma, H.-y., Tang, S., Van Weverberg, K., et al. (2018). CAUSES: Diagnosis of the summertime warm bias in CMIP5 climate models at the ARM Southern Great Plains site. *Journal of Geophysical Research: Atmospheres*, 123, 2968–2992. https://doi.org/10.1002/2017JD027200f

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