A31L-1909: Kilometer-scale downscaling of CESM2 Large Ensemble simulations over CONUS

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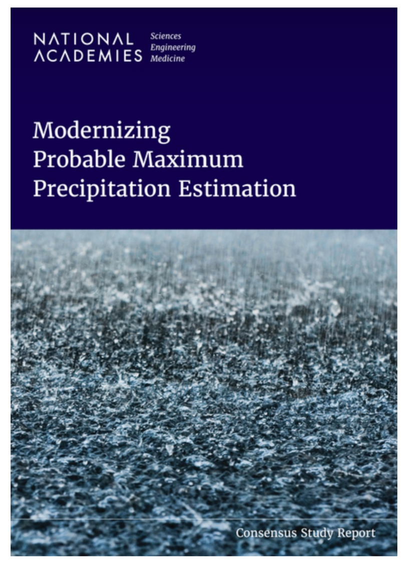
1. Motivation



- In 2022, Bipartisan Infrastructure Law gives NOAA support to modernize probable maximum precipitation (PMP) and funds National Academies of Sciences (NASEM) study[1] to issue recommendations
- PMP – maximum depth of precipitation over a given area and duration that is meteorologically possible
- NASEM study Recommendation 5-10: **model-based approach to PMP estimation through multi-model large ensembles of km-scale continuous climate simulations**
- Requires dynamical downscaling of a variety of global climate models onto a conterminous US (CONUS) grid in the Weather Research and Forecasting (WRF) model
- NCAR's CESM2 Large Ensemble[2] provides 10 individual ensemble members with high frequency output
- Intention is that downscaled climate dataset will have broad research applicability in addition to PMP

2. Pre-existing kilometer-scale simulations over CONUS

CONUS404

- Citation: Rasmussen et al. (2023)[3]
- 40+ simulation years (WY1980-2022)
- 4 km resolution encompassing entire CONUS
- Dynamically downscales ERA5 reanalysis
- Skillfully simulates extreme precipitation

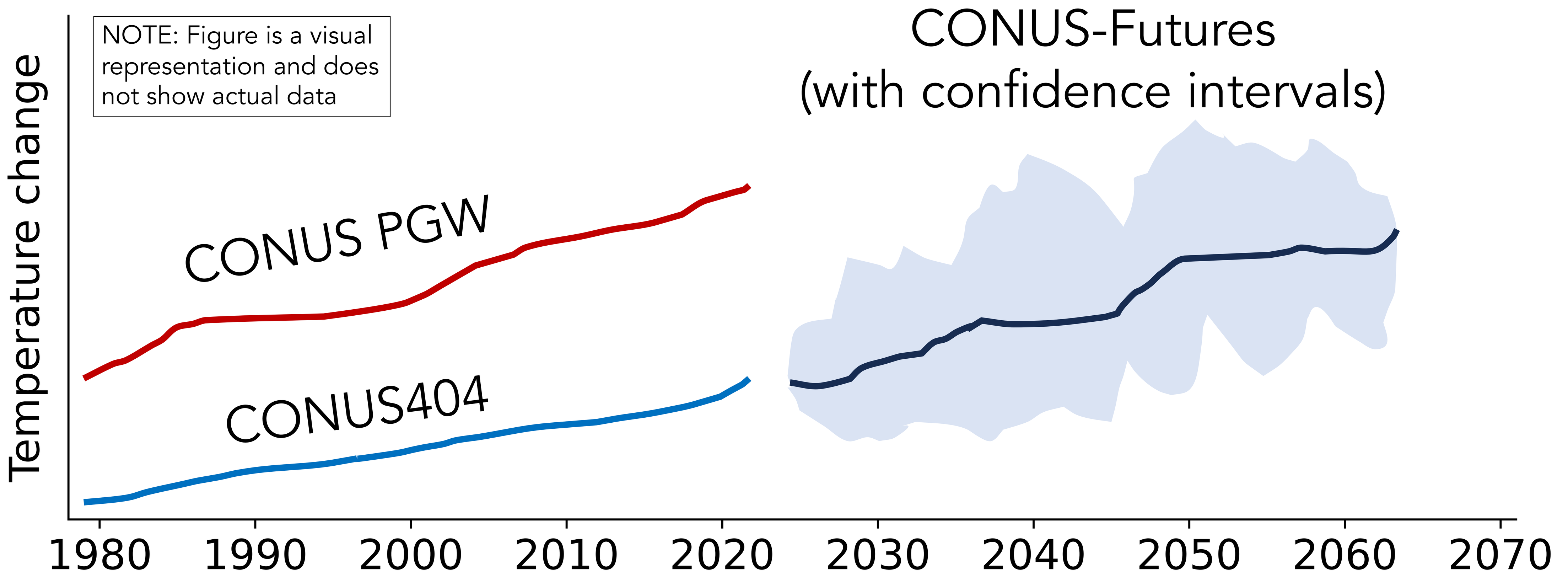
CONUS PGW (pseudo-global warming)

- Simulation was recently completed
- "Last 40 years of weather in the climate of the next 40 years"
- Applies delta to ERA5 reanalysis data based on CESM2 ensemble mean of future and historical periods
  - $PGW = CNTL + \Delta$; where $\Delta = FUTURE_{CESM2} - HIST_{CESM2}$

3. CONUS-Futures

- Same 4 km CONUS grid in WRF as used in CONUS404/PGW
- Each simulation is run for years 2025 – 2063 (planned)
- Begins by downscaling CESM2 Large Ensemble members
- Run on DOE/NOAA's Gaea supercomputer

Figure 1. Dynamically downscaled past and future simulations over CONUS



4. Simulation design and workflow

a. Single ensemble member from a global climate model (e.g., CESM2 Large Ensemble member 1191.010)

CESM2 Variable	*Time frequency*	*Dimensions*	*Units*
T	6-hourly	lev, lat, lon	K
Q	6-hourly	lev, lat, lon	$kg\ kg^{-1}$
U	6-hourly	lev, lat, lon	$m\ s^{-1}$
V	6-hourly	lev, lat, lon	$m\ s^{-1}$
Z3	6-hourly	lev, lat, lon	m
PS	6-hourly	lat, lon	Pa
PSL	6-hourly	lat, lon	Pa
TS	Daily	lat, lon	K
TSOI	Daily	levgrnd, lat, lon	K
H2OSOI	Monthly	levgrnd, lat, lon	$mm3\ mm^{-3}$
PHIS	Time invariant	lat, lon	$m^2\ s^{-2}$
LANDFRAC	Time invariant	lat, lon	fraction

Table 1. CESM2 input variables for WRF boundary conditions

b. Bias correct input data to remove systematic model bias

Method by Bruyère et al. (2014)[4]

$$ERA5 = \overline{ERA5} + ERA5' \ ; \ CESM = \overline{CESM} + CESM'$$

$$CESM_{bc} = \overline{ERA5} + CESM'$$

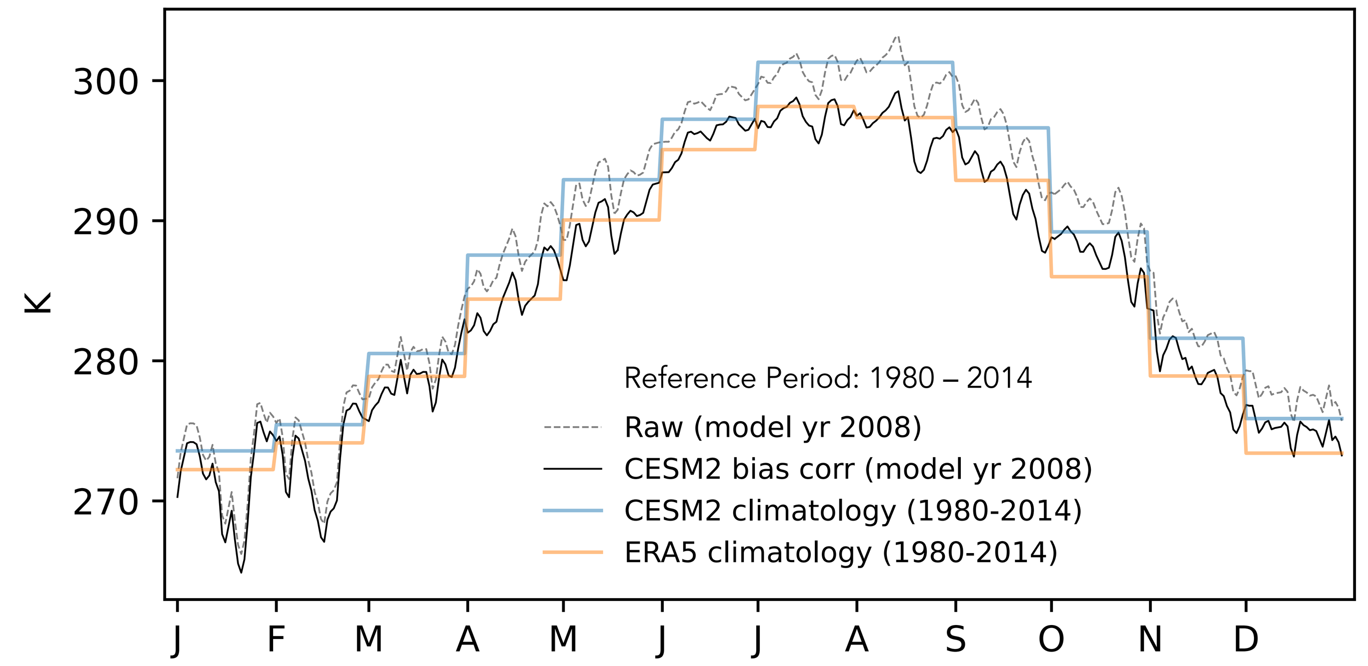


Figure 2. Bias correction of CONUS-average daily skin temperature

c. Convert bias corrected CESM2 input data into WRF-readable intermediate format

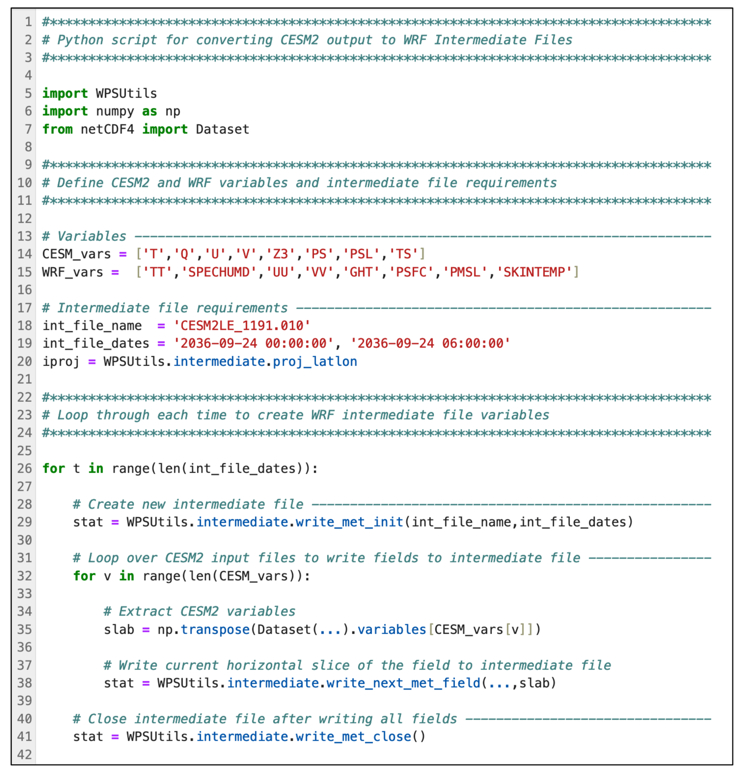


Figure 3. Python script for file conversion

d. Run historical and future simulations

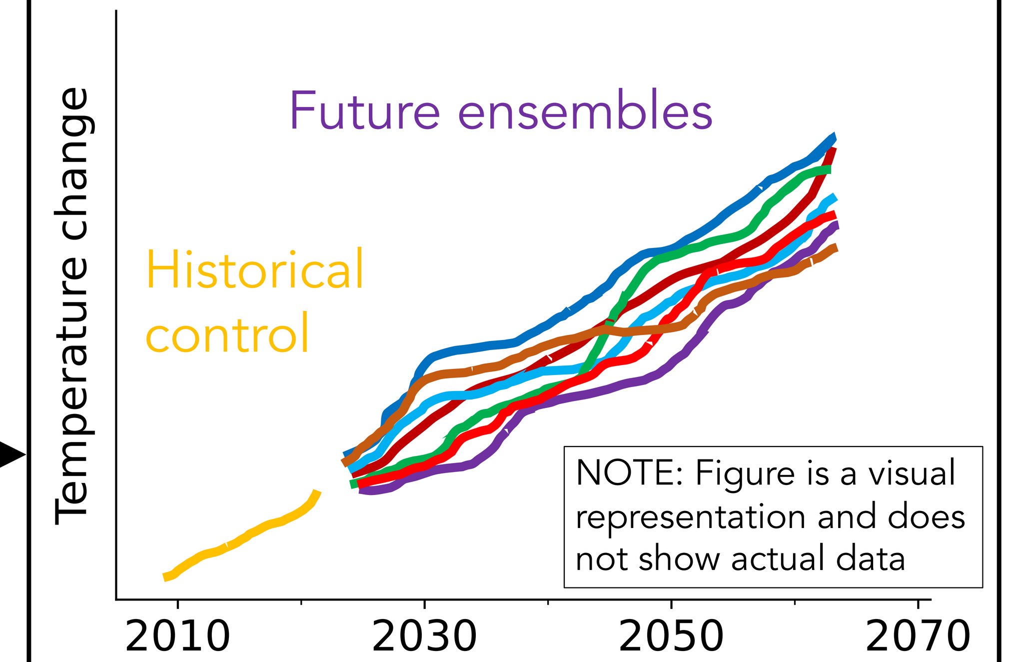


Figure 4. Future simulation plans

5. References

1) NASEM. (2024). *Modernizing Probable Maximum Precipitation Estimation.* DOI:10.17226/27460
2) Rodgers et al. (2021). *Earth System Dynamics.* DOI:10.5194/esd-12-1393-2021
3) Rasmussen et al. (2023). *BAMS.* DOI:10.1175/BAMS-D-21-0326.1
4) Bruyère et al. (2014). *Climate Dynamics.* DOI:10.1007/s00382-013-2011-6