Climate projections for the Chesapeake Bay and Watershed based on Multivariate Adaptive Constructed Analogs (MACA)

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CHAMP project needs

- Climate projections to serve as inputs to the Chesapeake watershed and estuarine models
- Climate variables:
  - air temperature
  - precipitation
  - humidity
  - downwelling shortwave and longwave radiation
  - wind velocity (magnitude and direction)
- Spatial resolution: at least $1/8^{o}$
- Temporal resolution: at least daily

Statistical downscaling solves two problems presented by GCMs:

- Spatial resolution is too coarse
- The models are biased

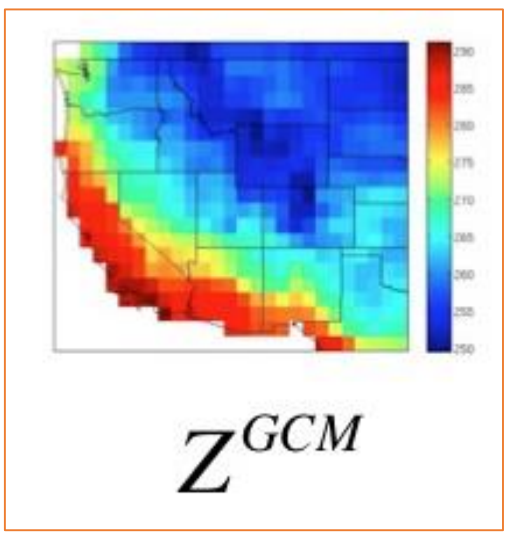
Why we use MACA among the many statistical downscaling choices:

- It has all the variables we need, except for downwelling longwave radiation
- It has the highest spatial resolution available ($1/24^o$)

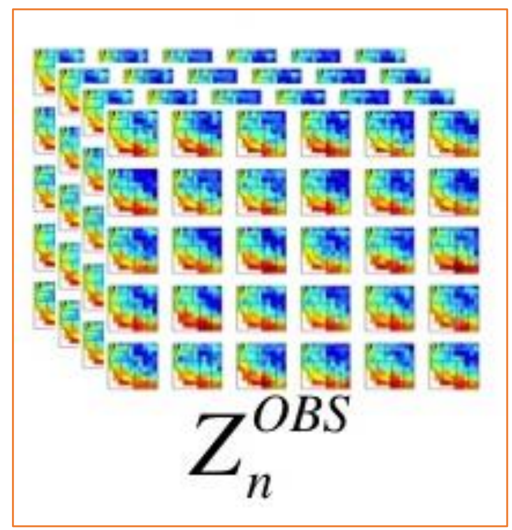
MACA uses constructed analogues

Step 1. For a given day of GCM output, find the top 10 days in the historical record that are closest (most analogous) to that GCM day

Single GCM day



Library of coarse observations within 45 calendar days of the GCM day

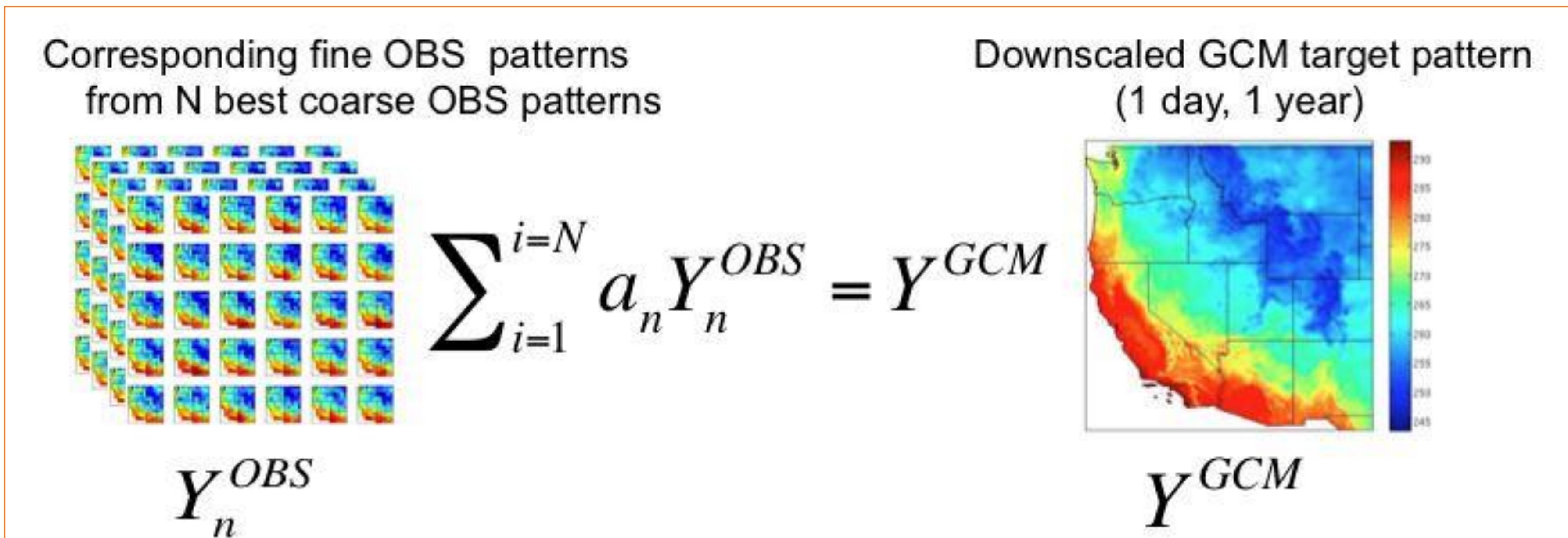


Method description: Abatzoglu and Brown (2012)

Step 2. Find the weights a_n for the top 10–100 days that best reconstruct the GCM day

$$Z^{GCM} \approx \sum_{i=1}^{i=N} a_n Z_n^{OBS}$$

Step 3. Apply those weights to the high-resolution observational data to get a high-resolution projection



Additional MACA details

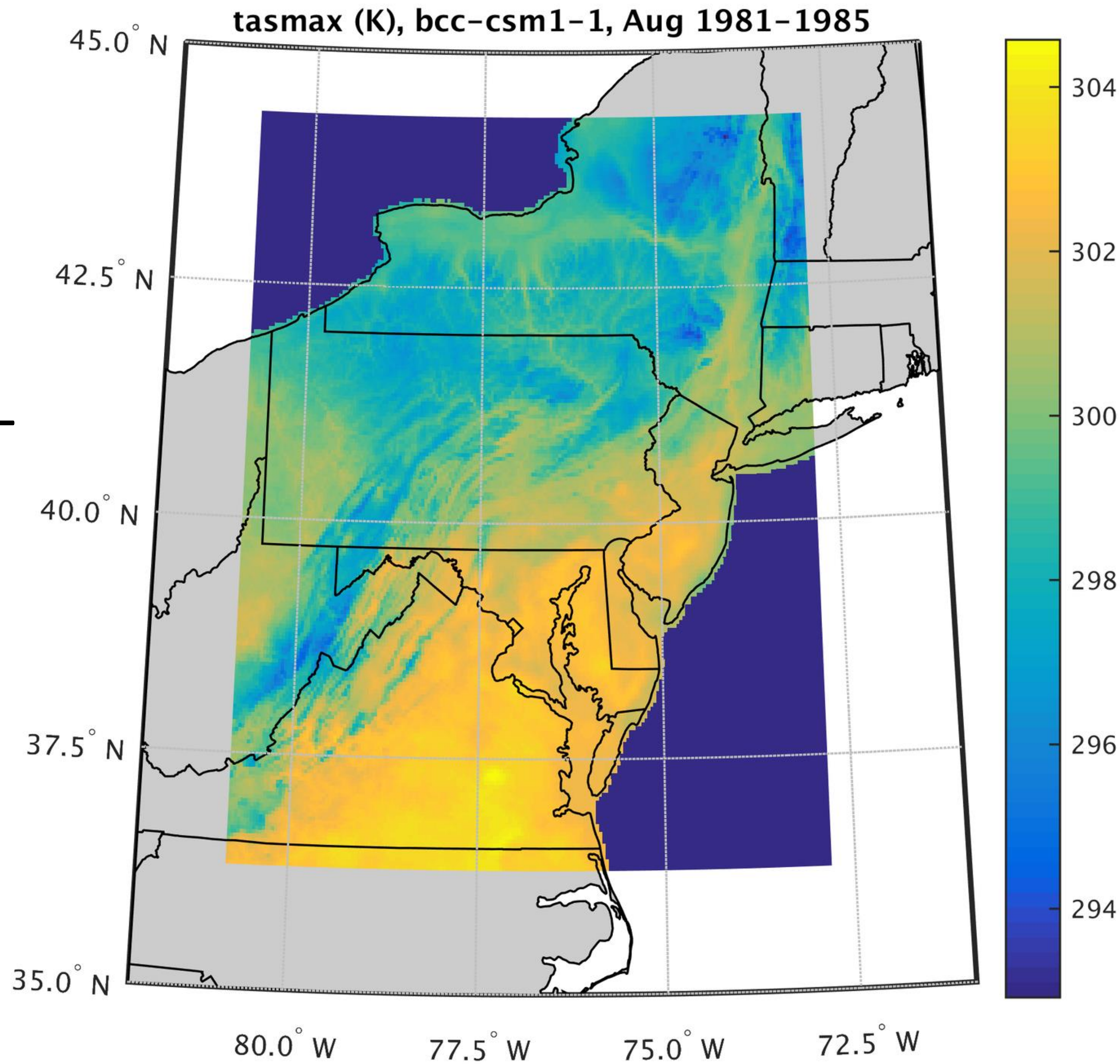
- Bias correction using quantile mapping
- Epoch adjustment to solve the problem of disappearing analogues (”adaptive”)
- 20 CMIP5 GCMs
- 2 emissions scenarios (RCP 4.5 and 8.5)
- 2 meteorological training data sets
- 2 versions of the downscaling (using slightly different approaches for the constructed analogues, bias correction, and epoch adjustment)

Delta approach for first cut

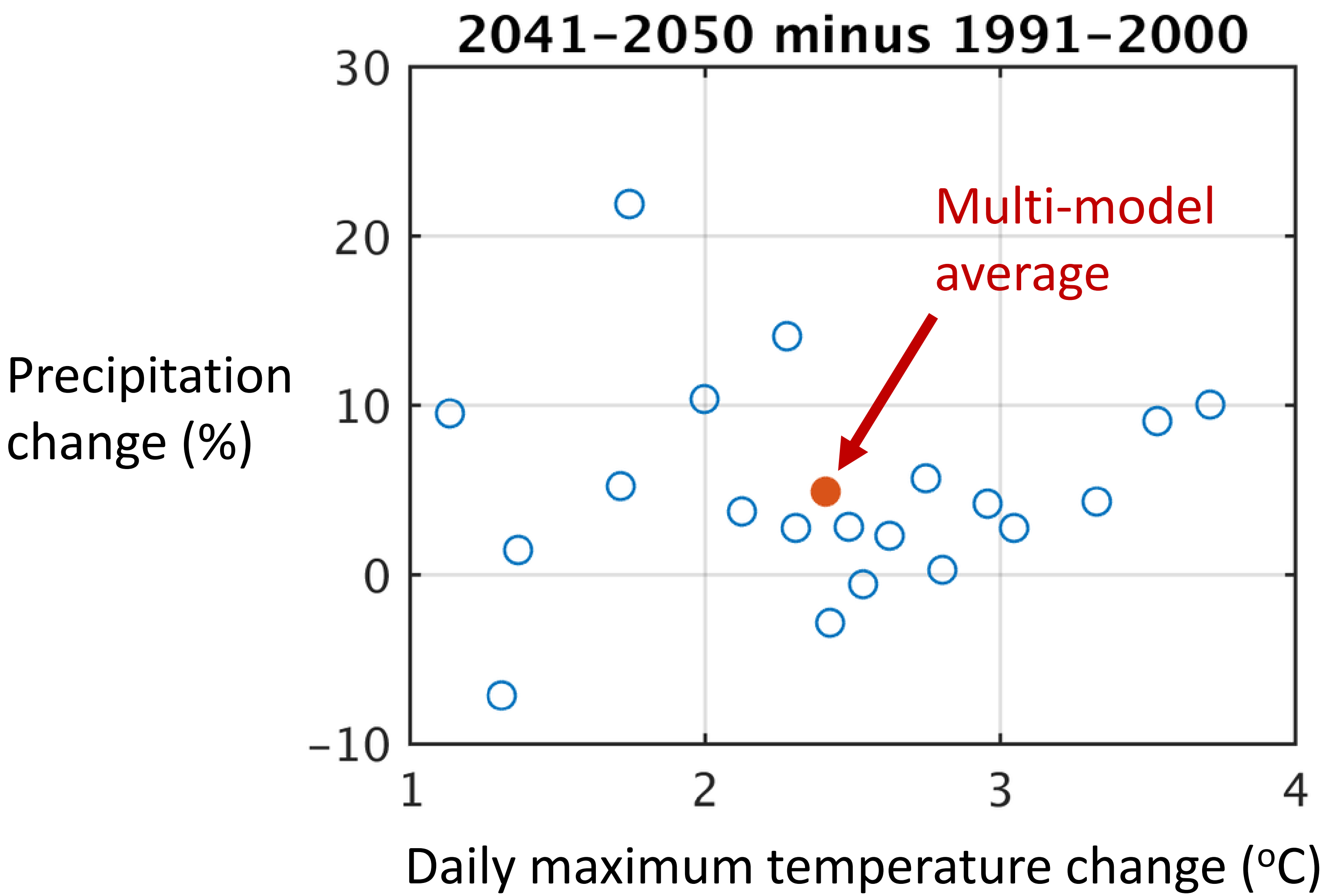
- MACAv2 with METDATA training data
- RCP8.5
- All 20 models and multi-model average
- PSU to provide mean annual cycles at monthly resolution in 5-year averages: 1981–1985, 1986–1990, … , 2046–2050

Example output:

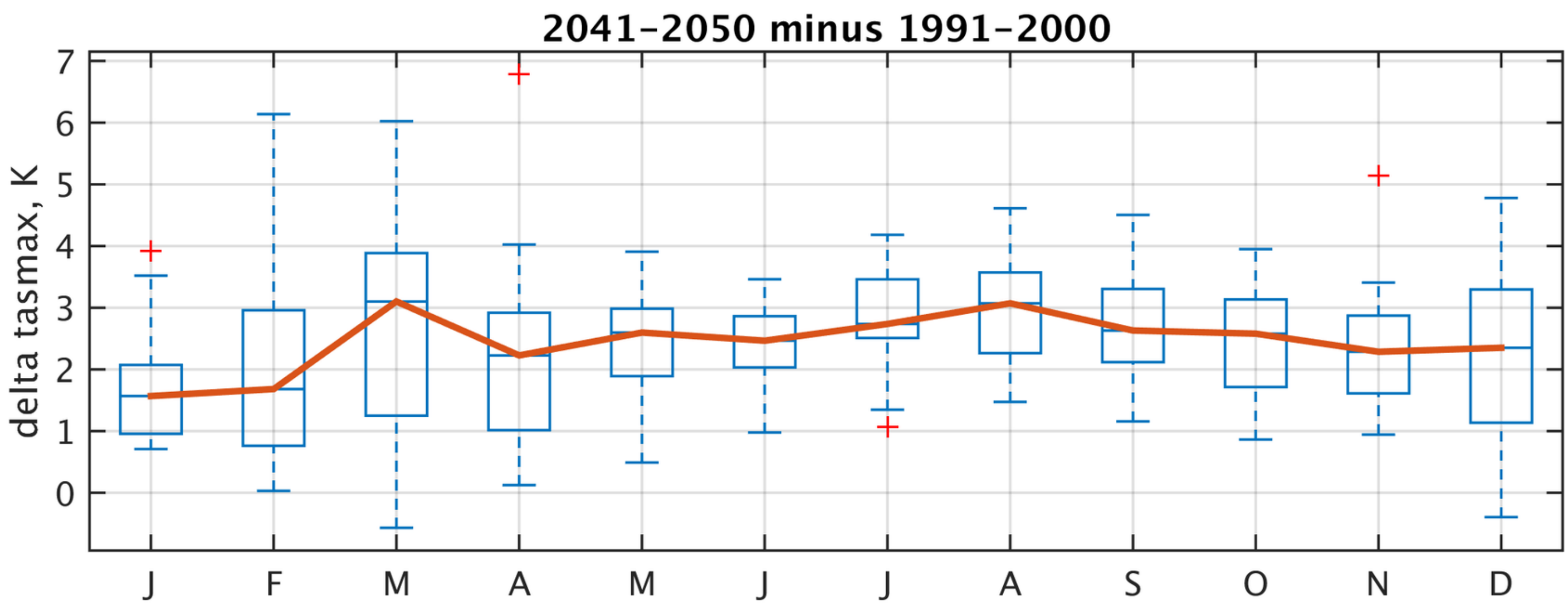
- daily max temperature
- August, 1981–1985
- GCM BCC-CCSM1-1



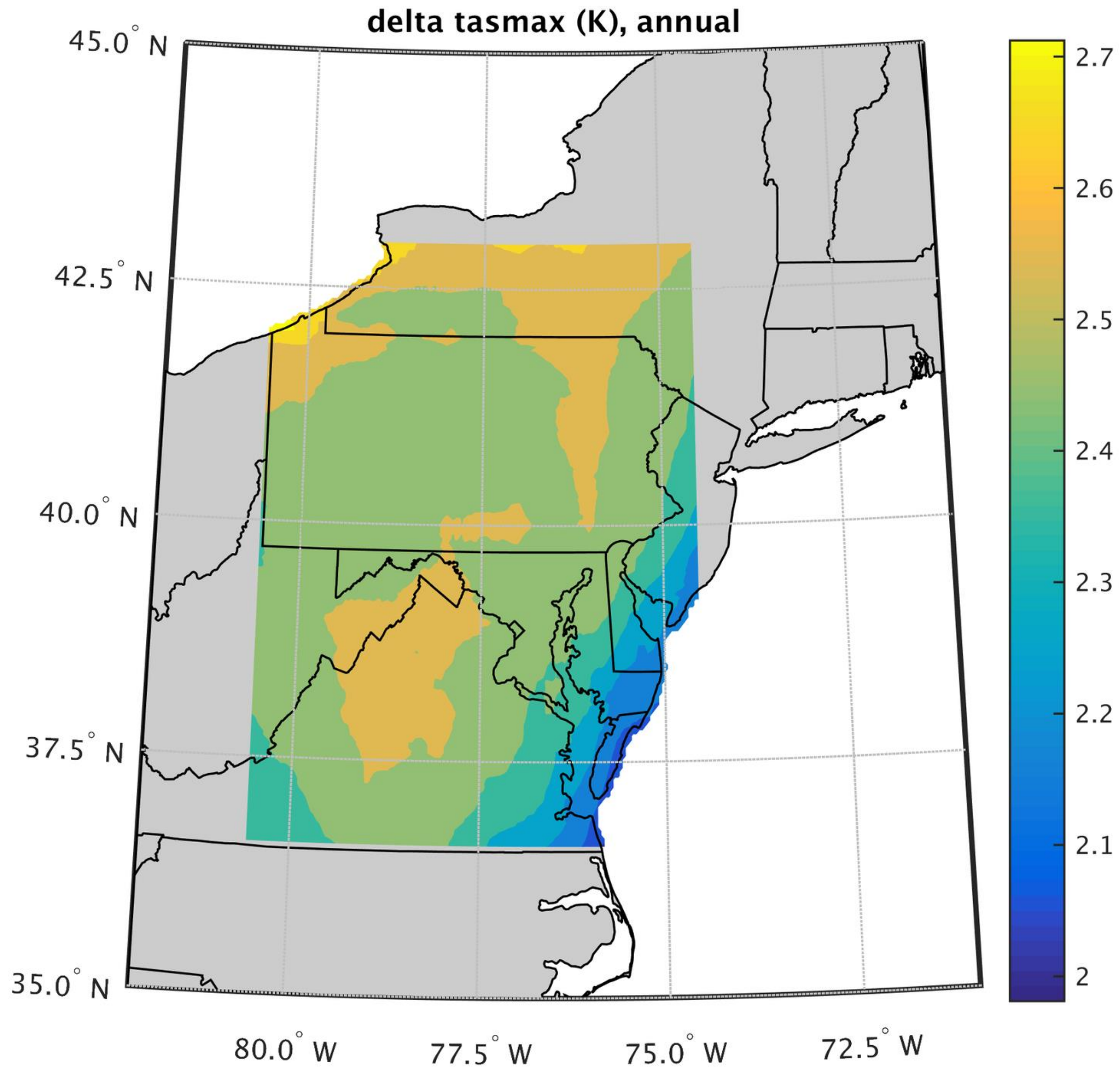
Projected annual temperature and precipitation change by the 20 GCMs



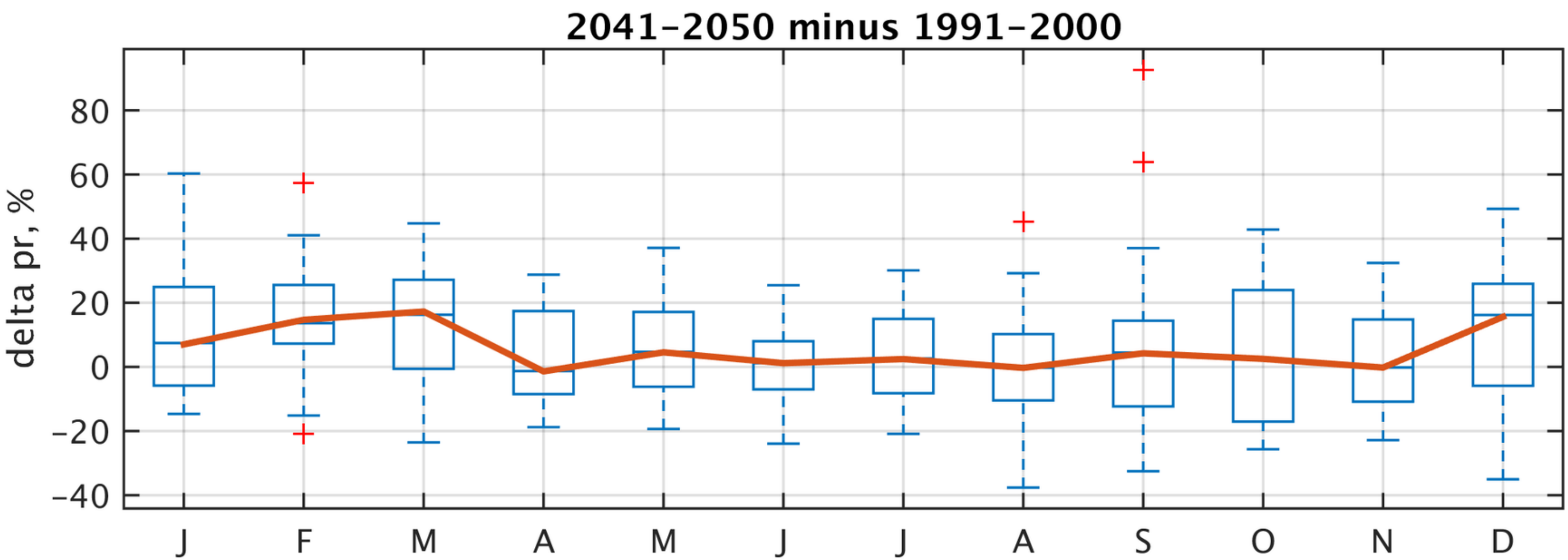
Projected change in annual cycle of daily maximum temperature



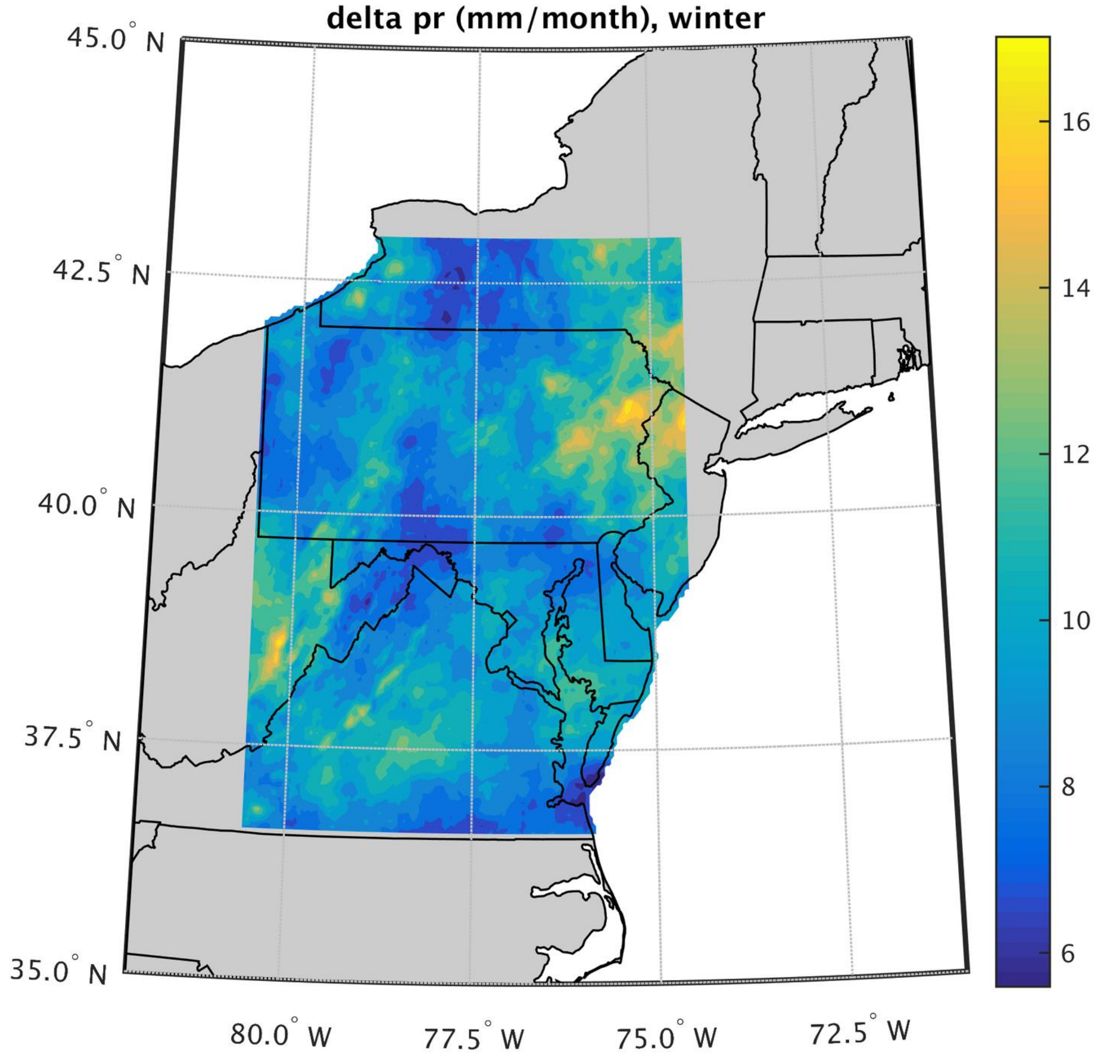
Projected change in daily maximum temperature, 2041–2050 minus 1991–2000



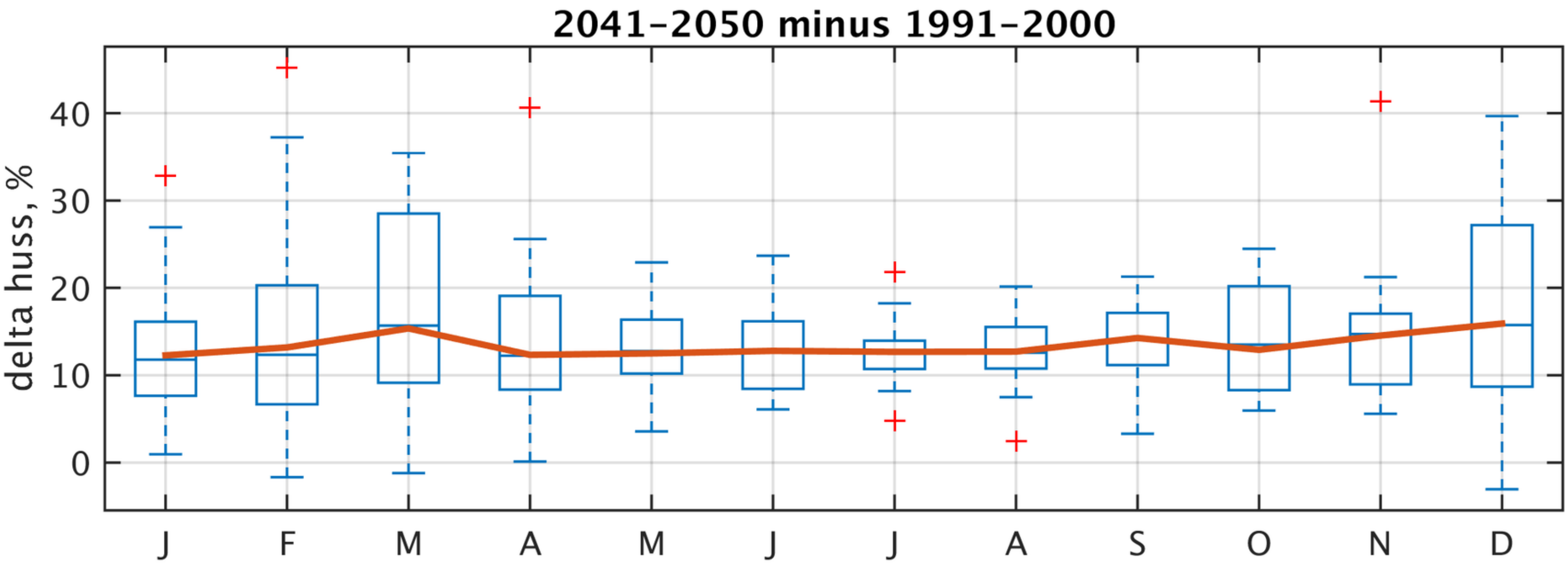
Projected change in annual cycle of precipitation



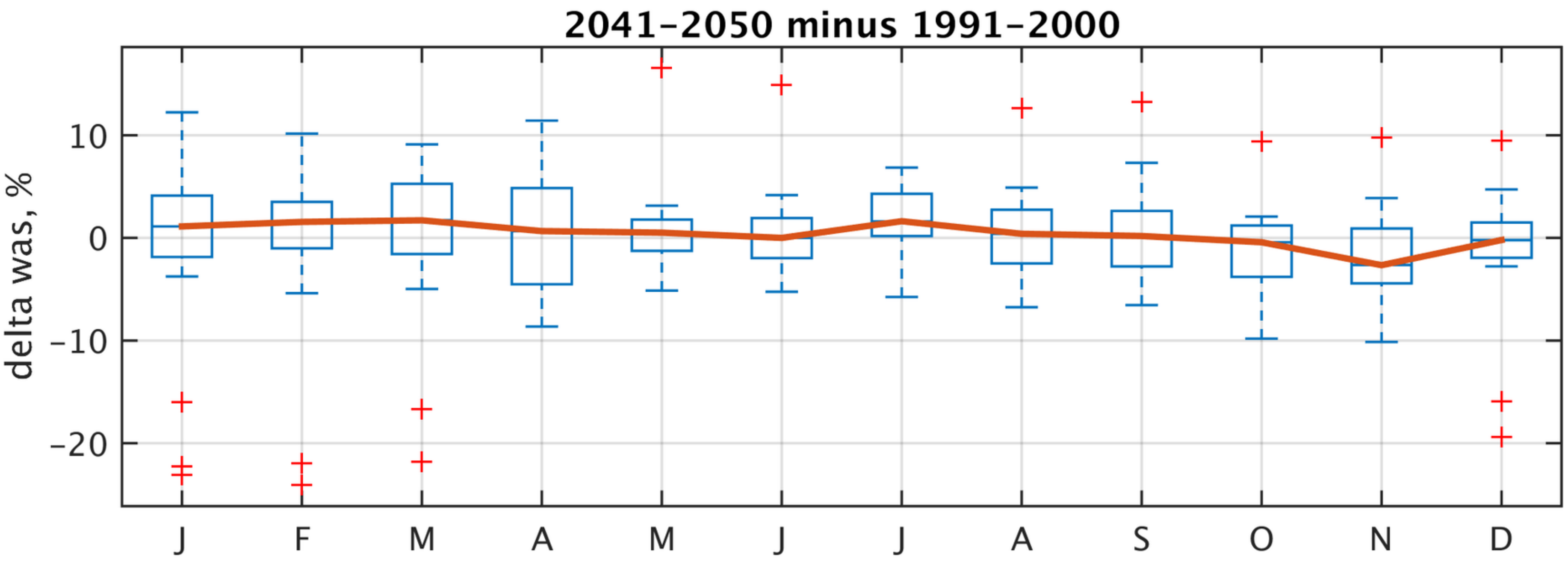
Projected change in winter precipitation, 2041–2050 minus 1991–2000



Projected change in annual cycle of specific humidity



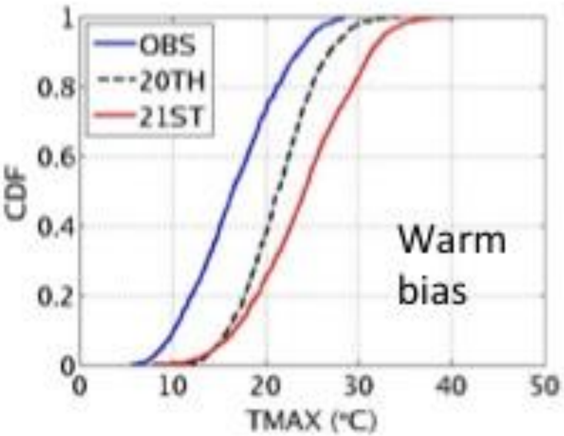
Projected change in annual cycle of wind speed



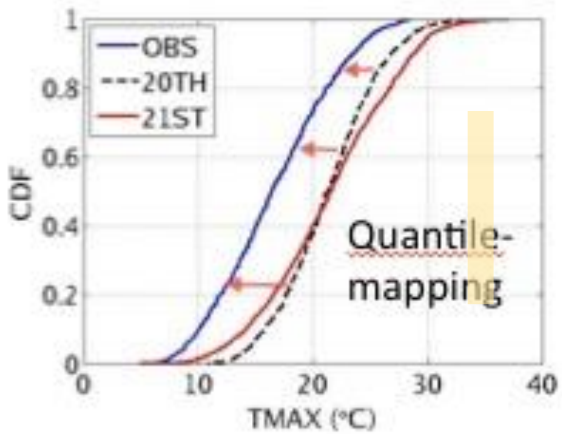
Next steps

- Process solar radiation and wind components output
- Model longwave radiation change from other variables
- Place model output on a server for use by Auburn, VIMS, and the CBP

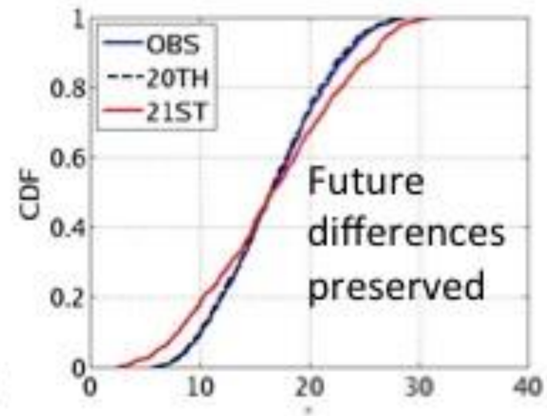
Extra slides



Raw GCM Data



After Epoch Adjustment



After Bias Correction

Differences between MACAv1 and MACAv2 downscaling

Epoch adjustment: variables
In v2, the trend in all variables is removed at the start.
In v1, the trend for only tasmax/tasmin,uas/vas was removed at the start.

Epoch adjustment: periods
In v2, the trend is removed for both the historical and future periods.
In v1, the trend was only removed in the future period.

Bias correction at coarse scale: preserving trends
In v2, after the coarse bias correction of the multiplicative variables (i.e. pr, huss,wind speed), the trend is removed again (as the coarse bias correction can modify this trend).

Constructed Analogs: number of patterns
In v2, we use 10 patterns.
In v1, we use 100 patterns(there may be some overfitting here).

Constructed Analogs: the error
In v2, we interpolate the error in the constructed coarse pattern and add it to the constructed downscaling at the fine level.
In v1, we throw away the coarse error from the constructed analogs method.

Bias Correction at Fine Scale: independently or jointly
In v2, we bias correct pr, huss, rsds independently, but bias correct tasmax and tasmin jointly with the corrected precipitation.
In v1, we bias correct all variables independently.

METDATA

- Spatial resolution of 1/24-degree (~4-km)
- Daily timescales
- Variables: near-surface minimum/maximum temperature, minimum/maximum relative humidity, precipitation, downward solar radiation, **wind components**, and specific humidity.

This dataset was created by bias-correcting daily and sub-daily mesoscale reanalysis and assimilated precipitation from the NASA North American Land Data Assimilation System (NLDAS-2, Mitchell et al., 2004) using monthly temperature, precipitation and humidity from Parameter-elevation Regressions on Independent Slopes Model (PRISM, Daly et al., 2008). The data were validated against an extensive network of weather stations including RAWS, AgriMet, AgWeatherNet, and USHCN-2 showing skill in correlation and RMSE comparable to that derived from interpolation using station observations.

Comparison of the three available MACA data products

	MACAv1-METDATA	MACAv2-LIVNEH	MACAv2-METDATA
Status	Available	Available	Available
Training Dataset	Abatzoglou et. al, 2012 (Years 1979-2010)	Livneh et. al, 2013 (Years 1950-2011)	Abatzoglou et. al, 2012 (Years 1979-2012)
Resolution	4-km (1/24-deg)	~6-km (1/16-deg)	4-km (1/24-deg)
Spatial Extent	WUSA (31.02-49.1N, -124.77 to -103.02E)	Contiguous USA (CONUS) and Columbia Basin into Canada	Contiguous USA (CONUS)
Spatial Projection	WGS 1984 datum	WGS 1984 datum	WGS 1984 datum
Temporal Resolution	daily(on METDATA grid) monthly aggregations (adjusted to 4-km PRISM grid)	daily	daily
Temporal Extent	1950-2100	1950-2099	1950-2099
Downscaled Variables	tasmax,tasmin,rhsmax, rhsmin,pr,rsds, uas,vas,huss	tasmax,tasmin,pr, rsds,was,huss	tasmax,tasmin,rhsmax, rhsmin,pr,rsds, uas,vas,huss
Leap Days	No leap days	Yes, even if model excludes leap days	Yes, even if model excludes leap days
Size of individual netcdf files	3GB-daily, 100MB-monthly	2-4GB compressed-daily,0.1GB compressed-monthly	2.5GB-daily
Size of total dataset	13.7TB-daily, 0.3TB-monthly	5TB-daily,0.5TB-monthly	20TB-daily

List of CMIP5 GCMs used in MACA product

Model Name	Model Country	Model Agency	Atmosphere Resolution(Lon x Lat)	Ensemble Used
bcc-csm1-1	China	Beijing Climate Center, China Meteorological Administration	2.8 deg x 2.8 deg	r1i1p1
bcc-csm1-1-m	China	Beijing Climate Center, China Meteorological Administration	1.12 deg x 1.12 deg	r1i1p1
BNU-ESM	China	College of Global Change and Earth System Science, Beijing Normal University, China	2.8 deg x 2.8 deg	r1i1p1
CanESM2	Canada	Canadian Centre for Climate Modeling and Analysis	2.8 deg x 2.8 deg	r1i1p1
CCSM4	USA	National Center of Atmospheric Research, USA	1.25 deg x 0.94 deg	r6i1p1
CNRM-CM5	France	National Centre of Meteorological Research, France	1.4 deg x 1.4 deg	r1i1p1
CSIRO-Mk3-6-0	Australia	Commonwealth Scientific and Industrial Research Organization/Queensland Climate Change Centre of Excellence, Australia	1.8 deg x 1.8 deg	r1i1p1
GFDL-ESM2M	USA	NOAA Geophysical Fluid Dynamics Laboratory, USA	2.5 deg x 2.0 deg	r1i1p1
GFDL-ESM2G	USA	NOAA Geophysical Fluid Dynamics Laboratory, USA	2.5 deg x 2.0 deg	r1i1p1
HadGEM2-ES	United Kingdom	Met Office Hadley Center, UK	1.88 deg x 1.25 deg	r1i1p1
HadGEM2-CC	United Kingdom	Met Office Hadley Center, UK	1.88 deg x 1.25 deg	r1i1p1
inmcm4	Russia	Institute for Numerical Mathematics, Russia	2.0 deg x 1.5 deg	r1i1p1
IPSL-CM5A-LR	France	Institut Pierre Simon Laplace, France	3.75 deg x 1.8 deg	r1i1p1
IPSL-CM5A-MR	France	Institut Pierre Simon Laplace, France	2.5 deg x 1.25 deg	r1i1p1
IPSL-CM5B-LR	France	Institut Pierre Simon Laplace, France	2.75 deg x 1.8 deg	r1i1p1
MIROC5	Japan	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies,and Japan Agency for Marine-Earth Science and Technology	1.4 deg x 1.4 deg	r1i1p1
MIROC-ESM	Japan	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	2.8 deg x 2.8 deg	r1i1p1
MIROC-ESM-CHEM	Japan	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	2.8 deg x 2.8 deg	r1i1p1
MRI-CGCM3	Japan	Meteorological Research Institute, Japan	1.1 deg x 1.1 deg	r1i1p1
NorESM1-M	Norway	Norwegian Climate Center, Norway	2.5 deg x 1.9 deg	r1i1p1