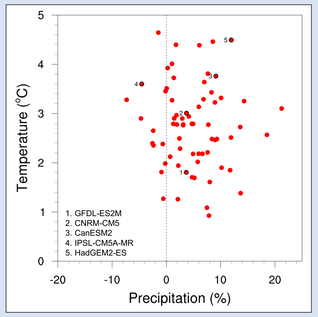
Downscaled Projections of Extremes in Evaporative Demand

Candida Dewes, Imtiaz Rangwala, Lesley L. Smith

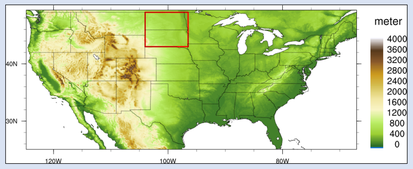
Cooperative Institute for Research in Environmental Science, University of Colorado Boulder
Physical Sciences Division, Earth Systems Research Laboratory, NOAA
candida.dewes@noaa.gov

Purpose and Scope of Work

- Drought conditions are initiated and/or exacerbated by enhanced evaporative demand (E_0)
- Several studies project severe to unprecedented drought conditions in western and central US due to increasing E_0 during 21st century
- E_0 projections are highly uncertain due to biases and differences between global climate models (GCMs)



Selection of five GCM scenarios based on changes in temperature and precipitation by mid-21st century (2036-2065 relative to 1976-2005) in the Northern Great Plains region (red box in the map below)



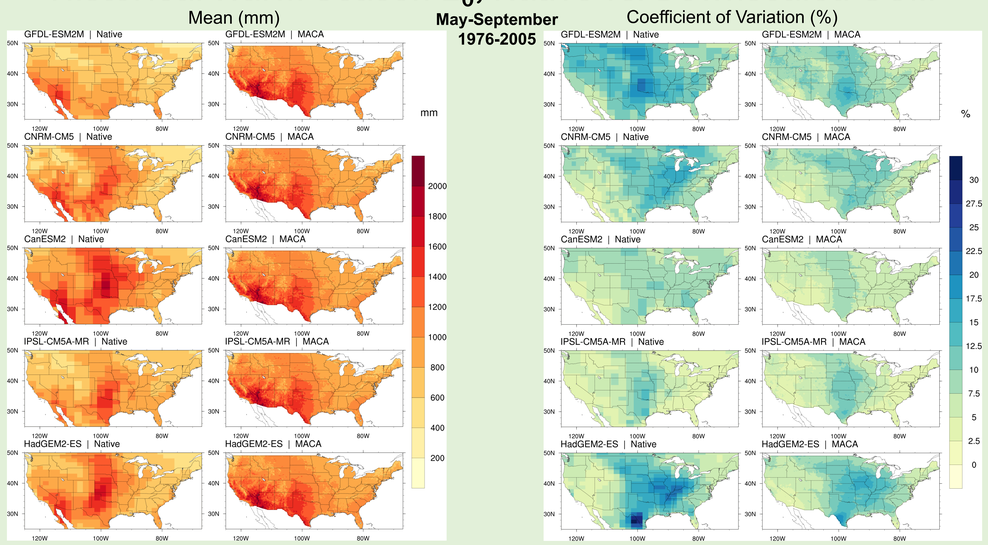
- In this study, we consider five divergent future climate scenarios to examine mid-21st century projections in E_0 from the Multivariate Adaptive Constructed Analogs (**MACA**) downscaled dataset at 4 km spatial resolution to assess future changes in E_0 and E_0 extremes

Selected CMIP5 models

model	country	agency	atmos res (deg lat x lon)	climate sensitivities (K) ECS	TCR
GFDL-ESM2M	USA	NOAA Geophysical Fluid Dynamics Laboratory	2.0 x 2.5	2.44	1.30
CNRM-CM5	France	National Centre of Meteorological Research	1.4 x 1.4	3.25	2.10
CanESM2	Canada	Canadian Centre for Climate Modeling and Analysis	2.8 x 2.8	3.69	2.40
IPSL-CM5A-MR	France	Institut Pierre Simon Laplace	1.25 x 2.5	4.13*	2.00*
HadGEM2-ES	UK	Met Office Hadley Center	1.25 x 1.88	4.59	2.50

ECS = equilibrium climate sensitivity *TCR = transient climate response*

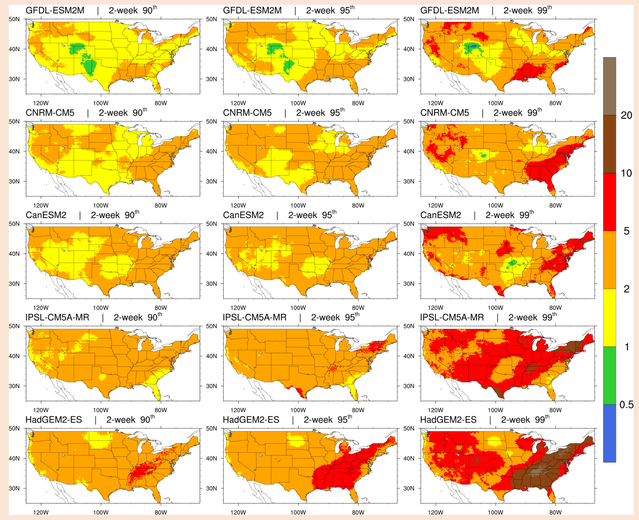
Historical Warm Season E_0, Native vs. Downscaled GCM



Comparison between native and downscaled projections for historical warm season E_0 indicates effectiveness of MACA bias-correction step while preserving the climate variability from the native GCMs

Changes in Extreme E_0 Conditions

Changes in probabilities of exceedance (as a multiplicative factor) of historical warm season **2-week E_0** 90th, 95th, and 99th percentiles by 2050

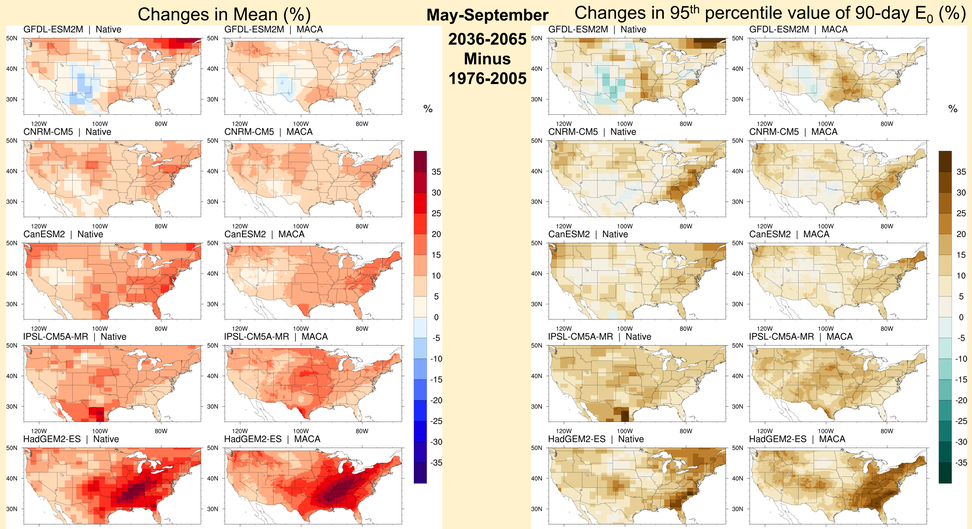


For the Northern Great Plains:

	99.9th	99th	95th	90th	75th	50th	25th	10th	5th	1st
GFDL-ESM2M	5.31	2.94	2.06	1.72	1.35	1.11	1.06	1.02	1.01	1.00
CNRM-CM5	7.98	4.78	2.90	2.40	1.73	1.28	1.13	1.04	1.02	1.00
CanESM2	10.19	4.47	2.80	2.28	1.67	1.28	1.13	1.04	1.02	1.00
IPSL-CM5A-MR	15.75	5.89	3.32	2.67	1.88	1.34	1.17	1.06	1.03	1.00
HadGEM2-ES	1.46	1.97	2.03	1.88	1.58	1.24	1.14	1.05	1.03	1.00

Most models point to at least a doubling in occurrence of extreme E_0 events. For the more rare events (99th and 99.9th percentile), inter-model differences are very large.

Changes in Warm Season E_0, Native vs. Downscaled GCM

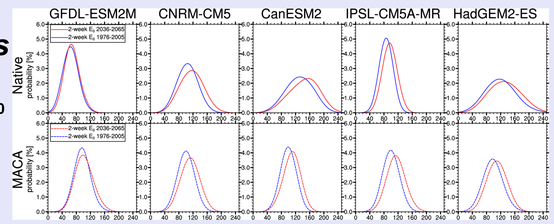


- The GCM selection depicts large differences in projected changes in the magnitude of **warm season (May-Sep)** mean and extreme E_0 (the latter illustrated specifically by the 95th percentile of 90-day E_0), and in some cases even direction of change. The MACA downscaling largely retains the magnitude and spatial character of change across models.
- *[Box to the right]* In examining the changes in distributions of warm-season 2-week and 90-day E_0 over the Northern Great Plains by 2050, in both native GCM and downscaled products, we see increases in the central tendency (i.e., mean) that is consistent with each model's climate sensitivity. In the MACA data, the inter-model differences are greatly reduced – benefit of the bias-correction process – while the rightward shift and widening of the PDF is mostly consistent with the changes projected by each model.

Changes in Warm Season E_0 distributions, Native vs. Downscaled GCM

Northern Great Plains

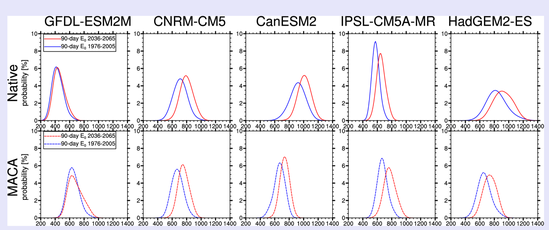
2-week E_0 (mm)



Changes (mm) in 2-week E_0 percentile thresholds, 2036-2065 relative to 1976-2005

		99.9th	99th	95th	90th	75th	50th	25th	10th	5th	1st
GFDL-ESM2M	**Native**	-3.2	3.7	5.2	5.2	2.9	2.6	4.5	4.3	4.5	3.9
	MACA	11.2	13.3	13.2	11.4	8.1	3.6	2.4	3.9	3.4	4.0
CNRM-CM5	**Native**	21.2	22.2	18.3	16.8	15.5	10.8	8.9	6.1	6.3	6.6
	MACA	8.3	14.1	15.4	15.3	13.8	12.2	9.9	7.5	8.0	7.2
CanESM2	**Native**	22.1	16.3	12.0	11.6	16.5	18.2	9.2	8.0	6.4	4.2
	MACA	16.9	16.5	11.5	11.5	11.1	11.1	9.6	7.1	3.9	2.3
IPSL-CM5A-MR	**Native**	14.3	17.3	14.3	12.8	11.4	10.2	9.5	9.0	7.3	8.2
	MACA	24.4	23.3	18.1	17.0	15.0	14.4	13.2	11.2	9.9	10.5
HadGEM2-ES	**Native**	1.5	9.8	16.2	18.4	16.5	11.8	8.9	7.4	7.4	9.9
	MACA	1.8	8.7	12.1	14.2	13.5	11.6	8.0	8.1	6.8	10.5

90-day E_0 (mm)

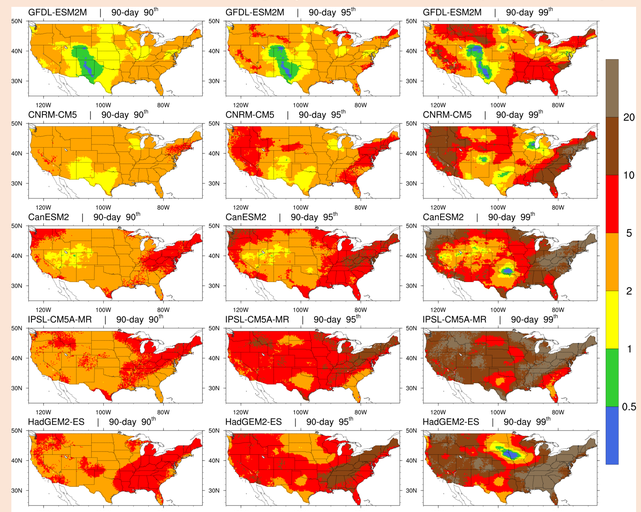


Changes (mm) in 90-day E_0 percentile thresholds, 2036-2065 relative to 1976-2005

		99.9th	99th	95th	90th	75th	50th	25th	10th	5th	1st
GFDL-ESM2M	**Native**	20.4	21.6	41.5	30.5	19.1	21.0	19.6	20.2	13.3	11.5
	MACA	3.5	24.0	84.7	73.6	52.3	20.8	13.7	16.8	13.3	7.1
CNRM-CM5	**Native**	30.6	42.8	97.8	99.3	86.8	84.6	89.3	104.2	102.5	74.3
	MACA	50.5	51.1	75.9	89.8	80.4	80.0	92.9	99.5	89.6	61.8
CanESM2	**Native**	68.5	73.5	65.0	72.3	83.6	92.1	99.2	137.6	140.9	165.2
	MACA	87.6	73.5	63.4	58.9	62.8	70.6	71.3	105.2	110.9	105.5
IPSL-CM5A-MR	**Native**	83.5	83.3	83.1	92.4	76.8	71.9	69.9	70.4	65.3	46.3
	MACA	103.2	100.2	101.4	120.1	109.5	94.5	93.1	97.1	89.8	64.8
HadGEM2-ES	**Native**	-10.5	-38.1	43.0	73.7	116.0	83.4	86.4	67.9	80.7	88.1
	MACA	1.2	-2.5	32.4	74.8	99.9	78.1	72.9	65.3	66.4	60.6

Changes in Extreme E_0 Conditions

Changes in probabilities of exceedance (as a multiplicative factor) of historical warm season **90-day E_0** 90th, 95th, and 99th percentiles by 2050



For the Northern Great Plains:

	99.9th	99th	95th	90th	75th	50th	25th	10th	5th	1st
GFDL-ESM2M	4.45	3.78	2.83	2.24	1.53	1.17	1.09	1.03	1.02	1.00
CNRM-CM5	10.94	7.15	4.39	3.73	2.49	1.59	1.32	1.09	1.04	1.01
CanESM2	27.56	9.15	5.07	3.75	2.38	1.56	1.30	1.10	1.05	1.01
IPSL-CM5A-MR	71.23	17.05	6.72	5.22	2.80	1.58	1.26	1.10	1.05	1.01
HadGEM2-ES	0.69	1.83	2.94	2.88	2.28	1.49	1.24	1.08	1.05	1.01

Patterns similar to the 2-week E_0, but increases in frequency are much larger. For the NGP region, most models point to at least a 3-fold increase in extreme seasonal evaporative stress. Again, very large differences across models for the most-rare events.

The risks for extreme evaporative demand across the conterminous US substantially increases by 2050 at both sub-seasonal and seasonal scales under all future scenarios barring some regional exceptions, e.g. the south-central US for the lowest-sensitivity GCM (GFDL-ESM2M).

Acknowledgements

MACA data: https://climate.northwestknowledge.net/MACA/ CMIP5 data: http://iacweb.ethz.ch/staff/beyerleu/cmip5/

This research is funded by DOI's North Central Climate Science Center through the project "Evaporation, Drought, and the Water Cycle across Timescales."