Late 20th Century Temperature Trends in the NARCCAP Regional Model Simulations

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Introduction

This poster displays simulations from the North American Regional Climate Change Assessment Program (NARCCAP) and their ability to reproduce the 2-m temperature trends of the late 20th century over North America. This analysis focuses on the simulations driven by the NCEP-DOE global reanalysis II (NCEP), and simulated trends are compared to this, as well as 2 other observation-based datasets and one other reanalysis.

Models and Methods

NARCCAP is producing 50-km horizontal resolution climate simulations over North America by dynamically downscaling 4 different global climate model (GCM) simulations and one reanalysis (NCEP) using 6 different regional climate models (RCMs). There are also 2 50-km timeslice experiments included in NARCCAP using the GFDL atmospheric model and the NCAR CCSM atmospheric model with observed sea-surface temperatures (SSTs) and sea-ice forcing the lower boundary.

Major characteristics of the NARCCAP RCMs:

	CRCM	ECP2	HRM3	MM5I	RCM3	WRFG
Dynamics	Nonhydrostatic, Compressible	Hydrostatic, Incompressible	Hydrostatic, Compressible	Nonhydrostatic, Compressible	Hydrostatic, Compressible	Nonhydrostatic, Compressible
Lateral Boundary Treatment	9 points (Davies 1976); spectral nudging of horizontal wind.	Perturbations relaxed at boundaries; spectral filter	4 points (Davies and Turner 1977)	4 points (linear relaxation)	12 points (exponential relaxation)	15 grid points (exponential relaxation)
Land Surface	CLASS	NOAH	MOSES	NOAH	BATS	NOAH
Thermal/Water Layers	3/3	4/4	4/4	4/4	1/3	4/4
Vegetation Types	21 vegetation classes	13 classes	53 classes (Wilson and Henderson- Sellers 1985)	16 classes from USGS SiB model	19 classes	24 classes from USGS
Boundary Layer	Local K, gradient Richardson number formulation	Hong-Pan non-local K	First order turbulent mixing	Hong-Pan (MRF) countergradient, non-local K	Non-local K, countergradient flux	Yonsei Univ. (explicit entrainment)
Explicit Moist Physics	Removal of supersaturation	Removal of supersaturation	Prognostic cloud liquid and ice; liquid potential temperature	Dudhia simple ice	SUBEX, prognostic cloud water	Prognostic cloud liquid and ice, rain, snow
Cumulus Parameterization	Mass Flux	Simplified Arakawa-Schubert	Mass Flux, including downdraft	Kain-Fritsch 2	Grell with Fritsch-Chappell closure	Grell
Number of Vertical Levels	29	28	19	23	18	35
Type of Vertical Coordinate	Gal-Chen scaled-height	Normalized pressure	Hybrid terrain following & pressure	Sigma	Terrain following	Terrain following
Original Grid Size	160 x 135	161 x 136	171 x 146		160 x 130	155 x 130
Sponge Zone Depth (# grid pts.)	10	14/20 (x/y)	8		13	10.5
Length of Timestep	900 Seconds	100 seconds	300 Seconds	120 seconds	150 Seconds	150 seconds
Spectral Nudging	Yes	Yes	No	No	No	No

For more information on NARCCAP and these regional models visit:

www.narccap.ucar.edu

All NARCCAP simulations, reanalyses, and observation-based datasets used here have been regridded to a common 1/2 degree resolution grid.

Observation based datasets and reanalyses:

NCEP: NCEP/DOE global reanalysis II. T62 (approx. 209 km) horizontal resolution, 28 vertical levels. The driver for the regional models shown here.

NARR: North American Regional Reanalysis. 32-km horizontal resolution, 45 layers.

UDEL: University of Delaware air temperature and precipitation analysis. 1/2 degree resolution, global. (http://www.esrl.noaa.gov/psd/)

CRU: CRU TS3.0 analysis from the Climate Research Unit at the University of East Anglia. 1/2 degree resolution, global. (http://badc.nerc.ac.uk/data/cru)

Trends

Trends have been calculated for each grid box using linear regression on seasonal average timeseries. 90% confidence intervals for each grid box were established using a t-test. Significant trends are hatched.

References

Diffenbaugh, N.S., 2009: Influence of modern land cover on the climate of the United States. Clim. Dyn., DOI 10.1007/s00382-009-0566-z

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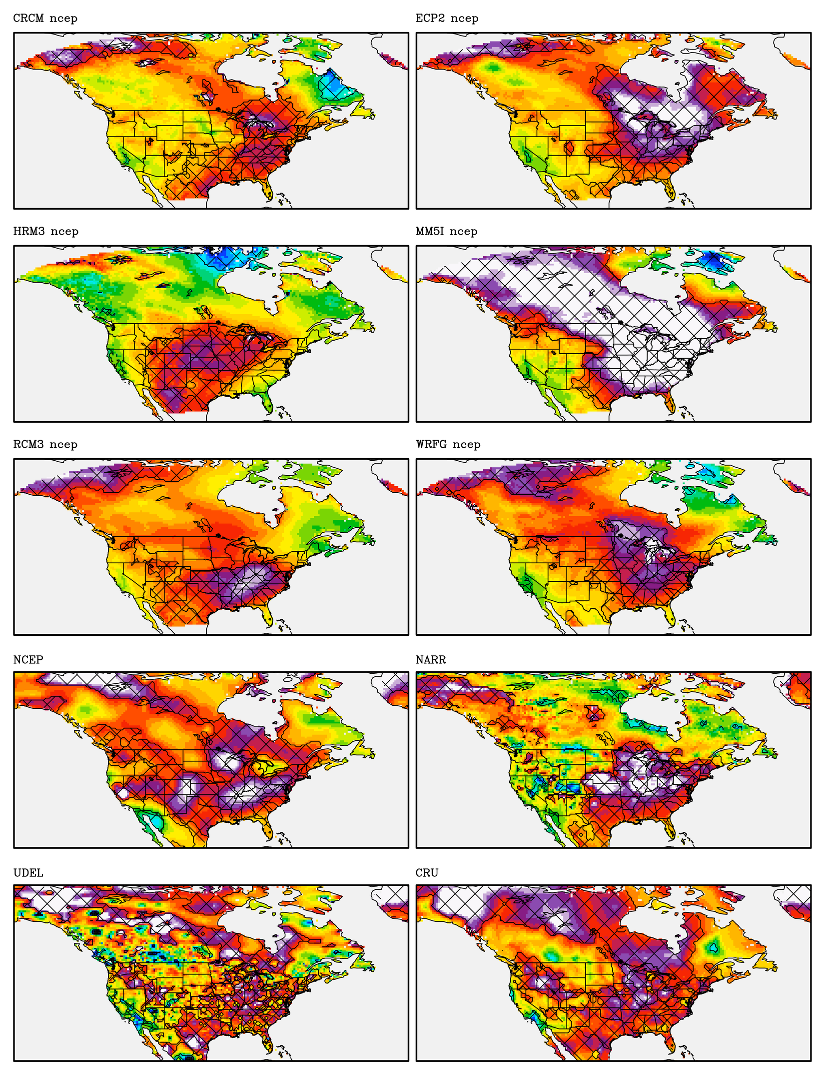
Portman, R.W., S. Solomon, G.C. Hegerl, 2009: Spatial and seasonal patterns in climate change, temperatures, and precipitation across the United States. PNAS, 106, 7324-7329.

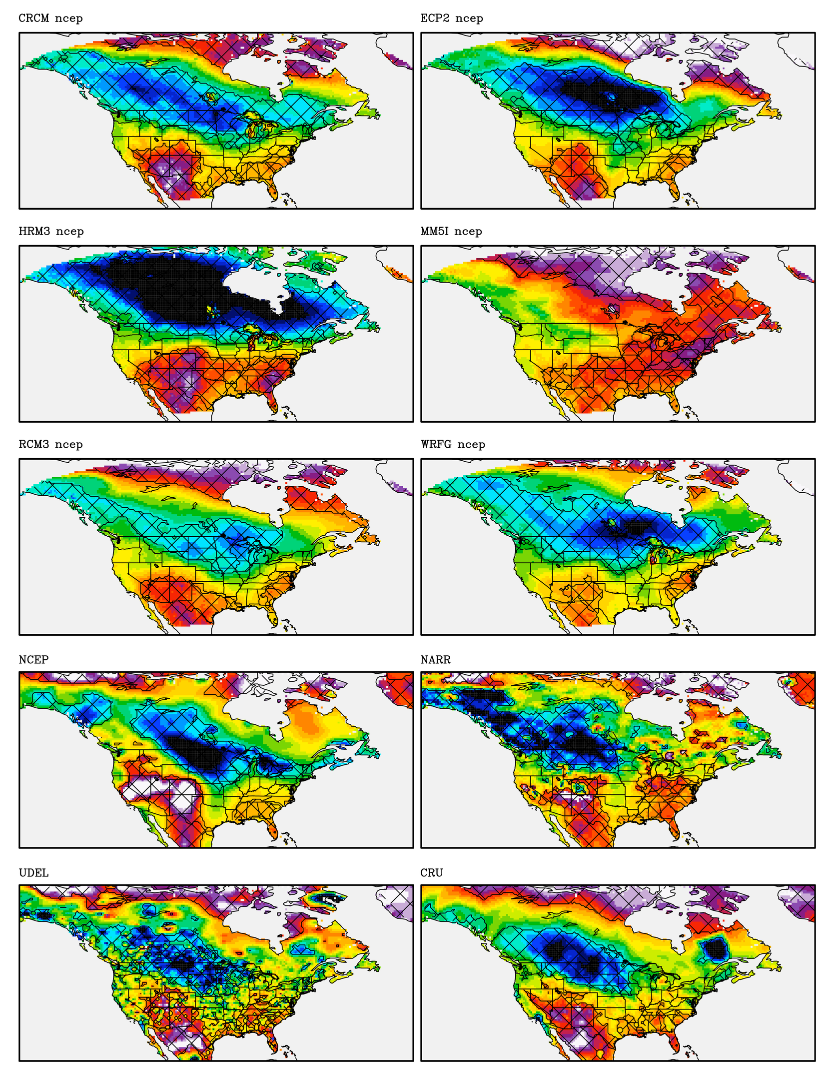
Wang, H., S. Schubert, M. Suarez, J. Chen, M. Hoerling, A. Kumar, P. Pegion, 2009: Attribution of the seasonality and regionality in climate trends over the United States during 1950-2000. J. Climate, 22, 2571-2590.

2-m Temperature Trends: 1980-2003

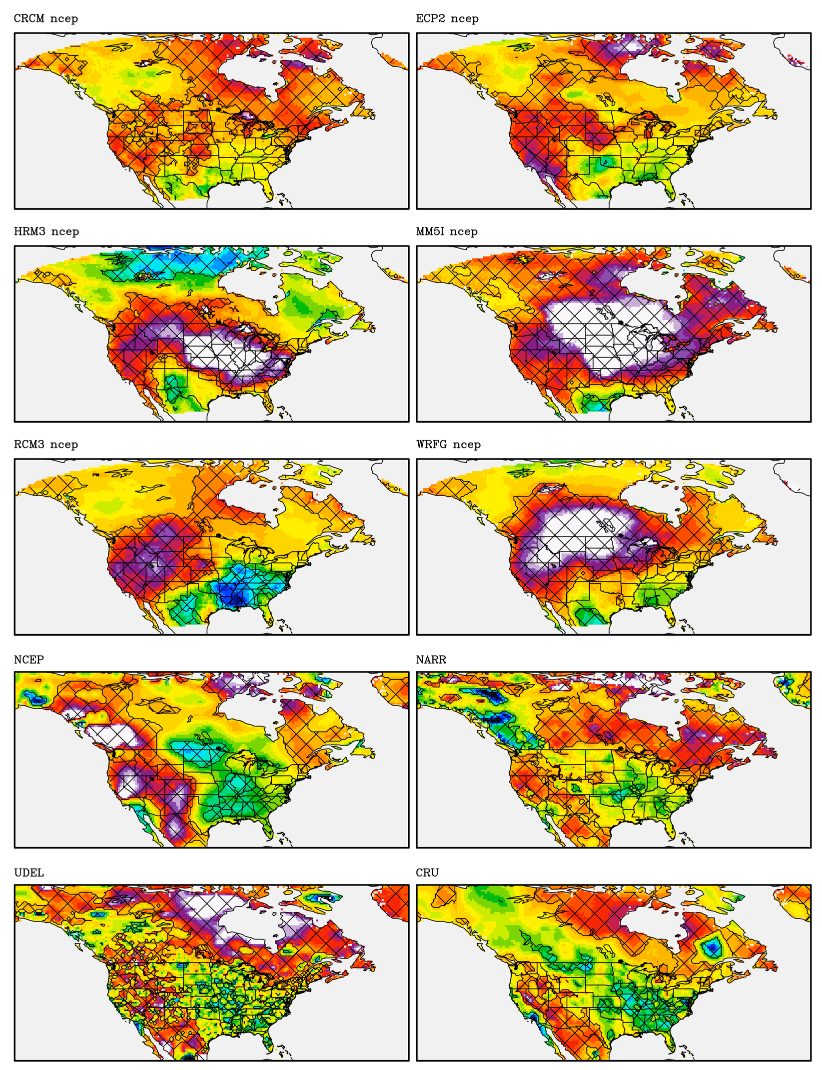
DJF



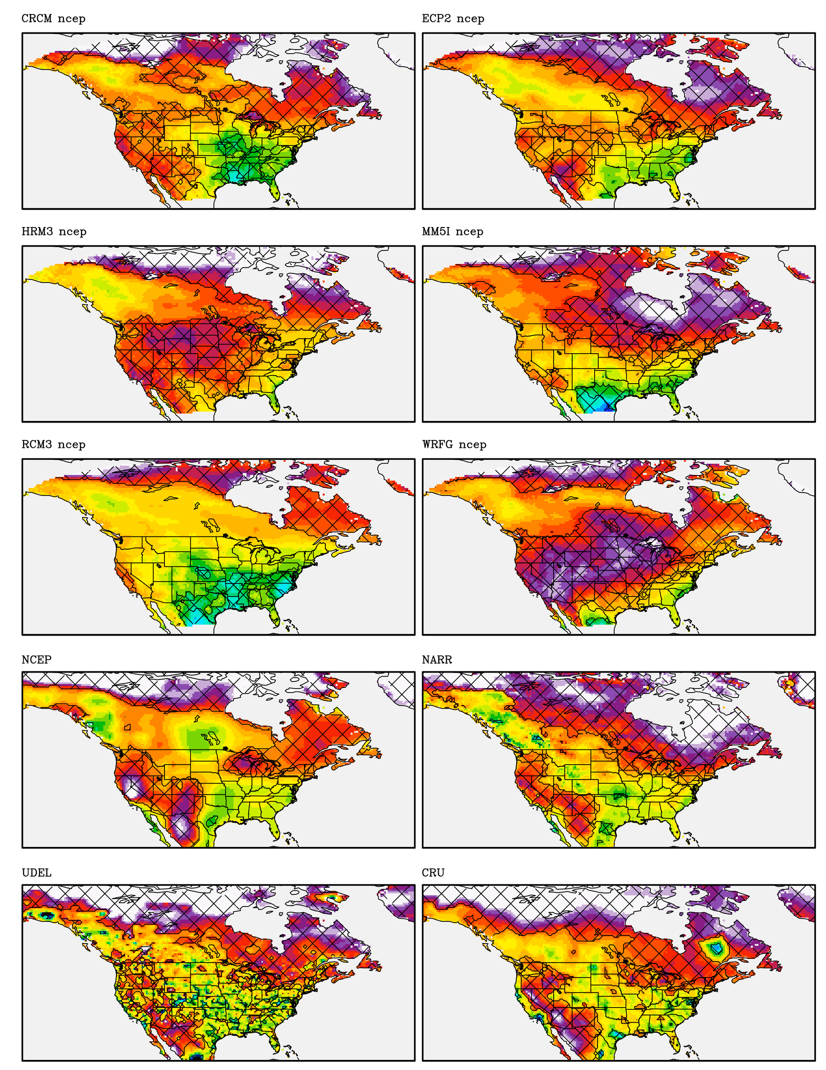
MAM



JJA



SON



Notable Trends...

» MAM cooling from the Great Lakes westward through British Columbia with warming in the Southwest and Southeast is captured in all of the regional models. The cooling trend is too weak in the MM5I, and too strong in the HRM3 relative to UDEL and CRU.

- » A particularly cold MAM season in 2002 is partially responsible for the strength of this cooling trend over this 24 year period, though it does exist during 1980-2000 to a lesser extent. In the area of cooling, the models do a particularly good job reproducing the interannual variability of temperature (not shown), including the 2002 MAM cold anomaly.
- » The overly strong Canadian MAM cooling trend in the HRM3 is echoed in winter where warming is too weak, and it also exists in the Northern territories in Summer.

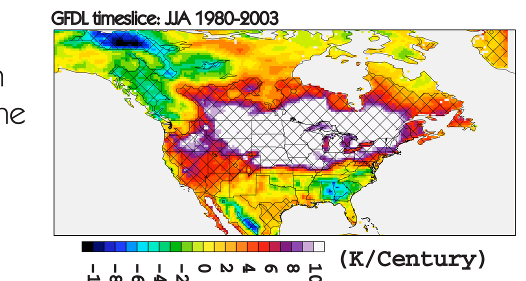
» The pattern of warming in DJF is also reasonably well captured by the RCMs, though there are some strong discrepancies in the magnitudes.

Notable Trends Continued...

The "Warming Hole"

» The "warming hole" in JJA - SON that extends from the Southeast U.S. northwestward through the Plains is not consistantly captured by the RCMs. More models are able to reproduce the cooling trend in the Southeast than in the Plains.

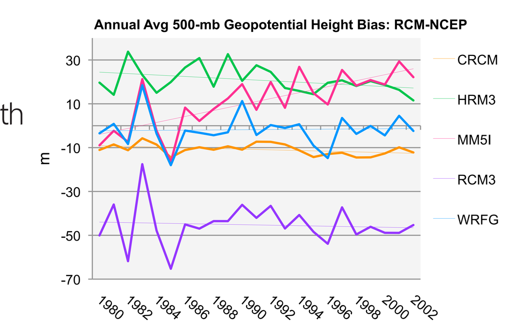
- » The "warming hole" is best simulated by the CRCM and the ECP2 - the 2 nudged models. The RCM3 also captures some of the non-warming trend in the Plains, but overdoes it in SON, particularly in the West.
- » In the Plains, this may be a response to Pacific decadal variability, enhanced by Atlantic multidecadal SST variability in SON (Wang et al. 2009). There are also possible contributions to the cooling from changes in land-surface type/use over time (Diffenbaugh 2009), though there is no clear consensus related to the causes yet (Portmann et al. 2009).
- » In the Southeast, the cooling could be the result of aerosols (Portmann et al. 2009).
- » If the "warming hole" is mainly caused by local influences that feed upscale (e.g. by land-surface change), it is logical that the RCMs would not capture this trend, as these effects are not included in the models.
- » If it is influenced by SST variability from outside of the domain, it is possible that the large-scale atmospheric influence may not translate well into the center of the domain, unless the model were nudged.
- » Given the potential influence of SSTs, the time-slice simulations forced by observed SSTs and run globally may capture the cooling in the Plains better than the RCMs. However, this is not the case in the GFDL timeslice. It does capture the cooling trend in the Southeast though.



Trends in Bias

» Some RCMs appear to be drifting from the solution of their driver. This is most noticably impacting the trends in the MM5I.

- » The MM5I has a strong warming bias to its trend in most seasons, especially in winter and summer. It appears to be consistently drifting further from its driver with time. This is reflected at the surface and at upper-levels.
- » This is illustrated for the domain average 500-mb geopotential height field in the chart to the right. The exact cause of this is as yet unknown, but it could be the result of error build-up and/or feedbacks occuring within the MM5I.



Discussion Points

» Should we expect regional climate models to be able to simulate observed trends?

- » Not all trends are forced at a large-scale and not all potential forcings are included in the RCMs.
- » Clearly, some RCMs cannot capture trends that occur over large portions of the domain. In the context of the "warming hole", if the forcing is external to the domain (e.g. SST multidecadal variability) and not due to changes in land type/use over the last 25 years, should we expect them to capture the trend?
- » Even in the case of small, but potentially resolvable changes in circulation, should we expect a reasonable trend? For example, examine the ability of the RCMs to capture the JJA cooling trend in coastal Southern California. This cooling may be due to a greenhouse gas forced increase in sea-breeze activity induced by greater warming inland vs. that over water (Lebassi et al. 2009).

» Should trends be used as a metric in weighting the RCMs, if that were to be done in NARCCAP?

- » One of the six weighting metrics developed within the ENSEMBLES program was based on temperature trends.

» Trends are unlikely to be captured in a more realistic manner in the GCM-driven simulations.

» There are potential implications for future projections and bias correction in this discussion of trends, particularly where trends in bias (drift) are concerned.

- » It is possible that bias may non-linear present-to-future, and it is also possible that any trend in the bias may be non-linear present-to future.
- » For instance, if the drift increases in the future simulation, there will be a bias to the trend in the future simulation, and, therefore, a bias in the projection as a result.

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