Climate Projections for the Midwest: Availability, Interpretation and Synthesis

Julie A. Winkler
Michigan State University

Raymond W. Arritt
Iowa State University

Sara C. Pryor
Indiana University

Goals

- Summarize by climate variable potential future changes in the Midwest as synthesized from currently-available peer-reviewed and gray literature.

Terminology

- Downscaling
  - Infer higher spatial or temporal resolution
  - Downscaling Methods
  - Dynamical downscaling
    - Use of numerical models such as regional climate models
  - Statistical downscaling
    - Empirical-dynamical downscaling
      - Surface variable is related to a circulation and/or free atmosphere variable
    - Disaggregation downscaling
      - Infer finer-scale values from coarse-scale spatial or temporal field of a particular variable (e.g., temperature)

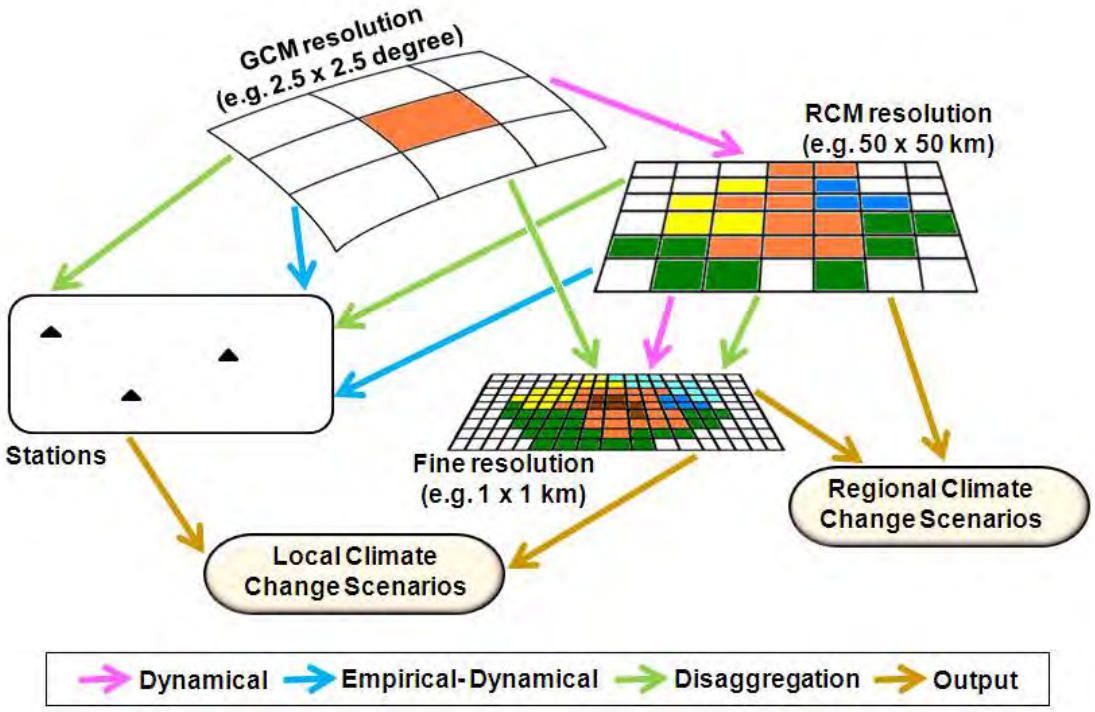


Figure 1. *Illustration of the spatial scales of climate projections, as developed using dynamical, empirical-dynamical, and disaggregation downscaling methods applied to GCM simulations. Note that multiple downscaling steps can be applied. SOURCE: Winkler et al., 2011a.*

NARCCAP

- North American Regional Climate Change Assessment Program
  - Regional climate model simulations driven both by reanalysis fields and by GCM results
  - Available for historical and mid-century time slices

Table 1: Available NARCCAP simulations.

Regional Climate Models (RCMs)	Global Climate Models (GCMs)				
	GFDL	*CGCM3*	*HADCM3*	*CCSM*	*NCEP*
CRCM		X		X	X
ECP2	X		X		X
HRM3	X		X		X
MM5I			X	X	X
RCM3	X	X			X
WRFG		X		X	X
ECPC					X
WRFP					X

SOURCE: http://www.narccap.ucar.edu/

Ensembles

- An ensemble is a suite of climate projections
- Provide an estimate of the "lower bound on the maximum range of uncertainty" (Stainforth et al., 2007)
- Ensemble means
  - Ensemble members are usually equally weighted
  - An ensemble mean can be misleading

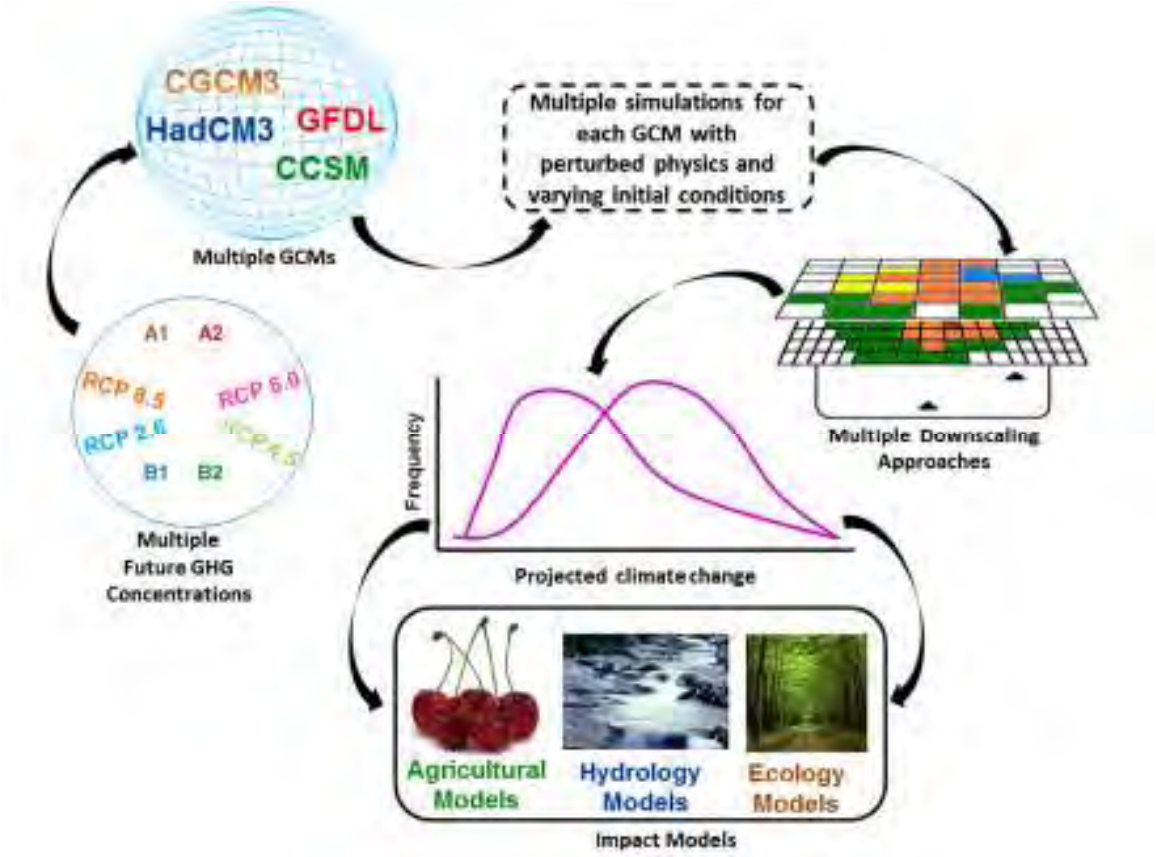


Figure 3. *Development of an ensemble of climate projections. The dashed line indicates uncertainty sources that are infrequently considered. Source: Winkler et al. 2011b.*

Projected Future Change

- Focused on temperature, precipitation and wind variables

CMIP3 GCM Temperature Projections (A1B emissions scenario)

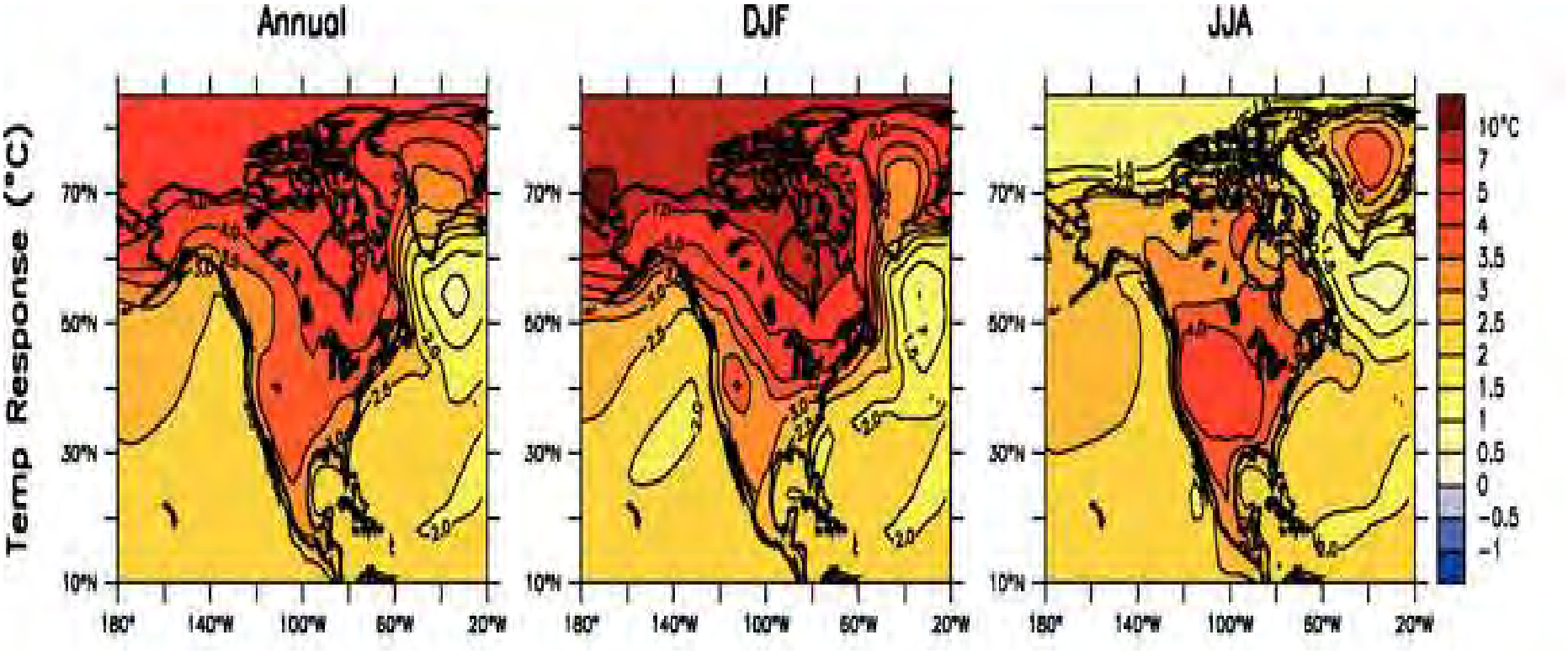


Figure 7. *Temperature and precipitation changes over North America from the MMD-A1B simulations. Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. OURCE: Christensen et al. 2007.*

- Annual increase (ensemble mean) of approximately 5.5°F in Midwest by 2080-2099

Temperature (Ensemble Means)

CMIP3 vs NARCCAP

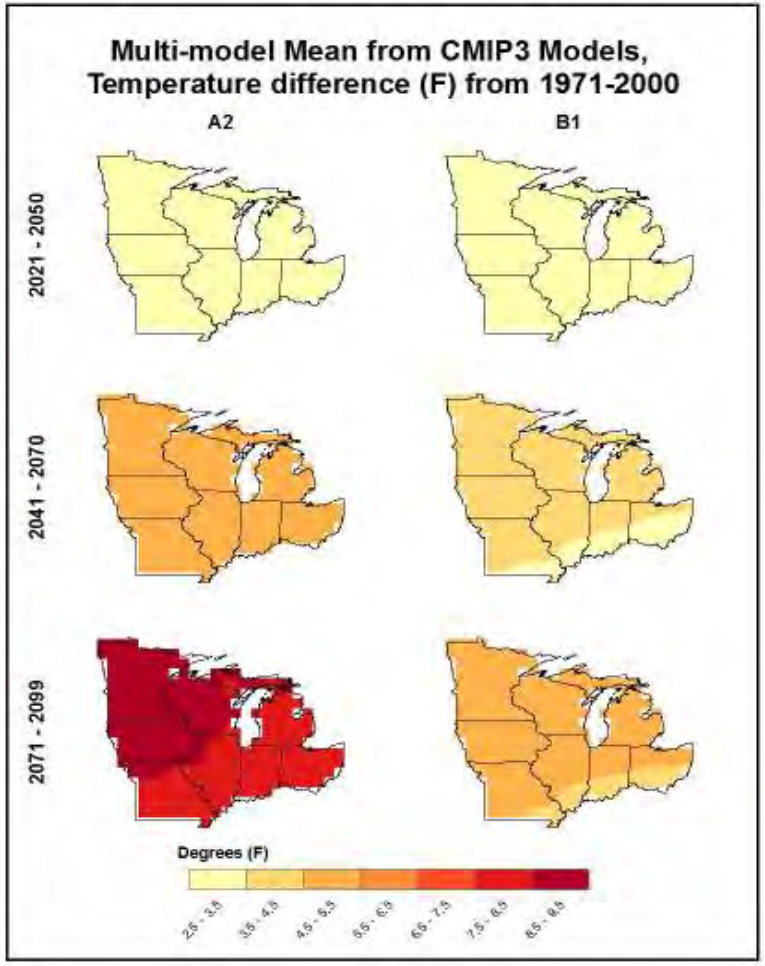


Figure 1. Multi-model mean annual differences in temperature (°F) between the 3 future periods and 1971-2000, from the 15 CMIP3 model simulations. SOURCE: Kunkel et al. 2012

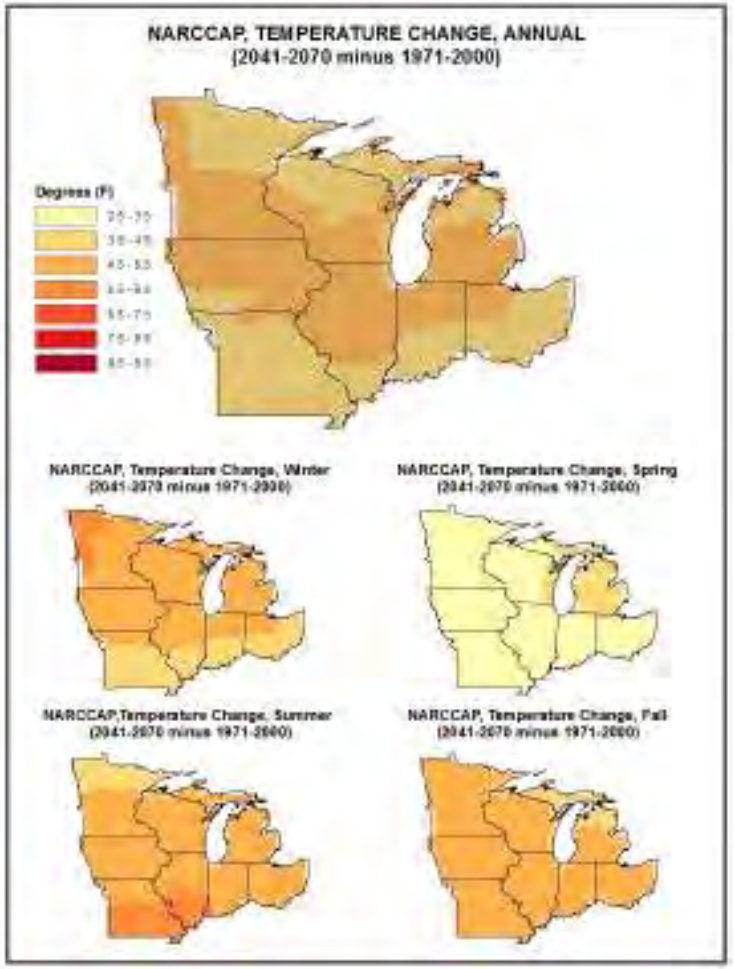


Figure 2. Multi-model mean annual and seasonal differences in temperature (°F) between 2041-2070 and 1971-2000, from the 9 NARCCAP regional climate model simulations. SOURCE: Kunkel et al. 2012

Temperature Thresholds and Indices: Heat Waves

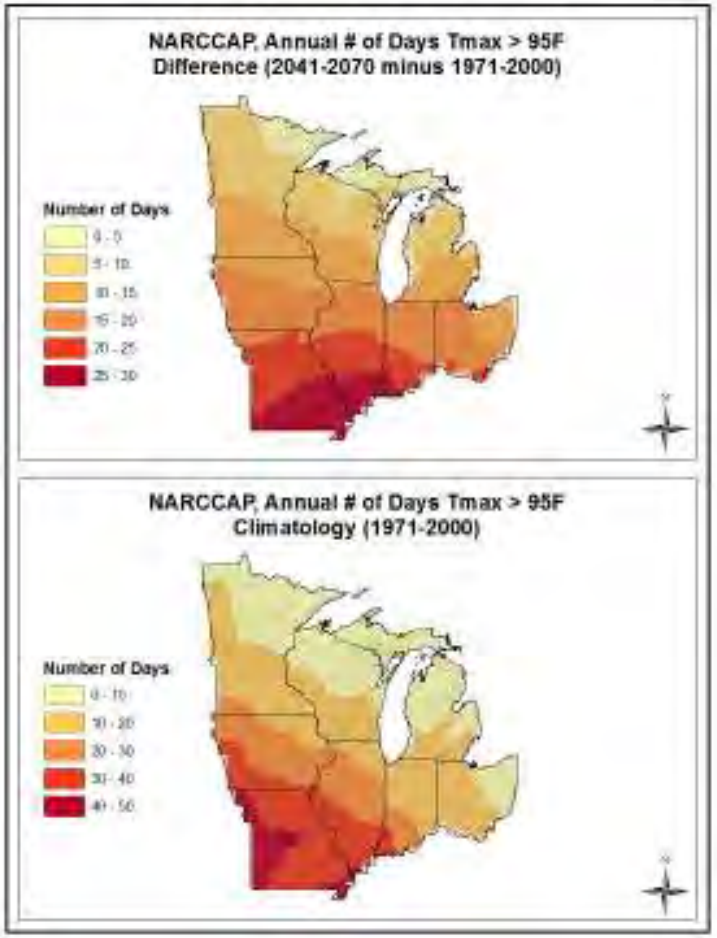
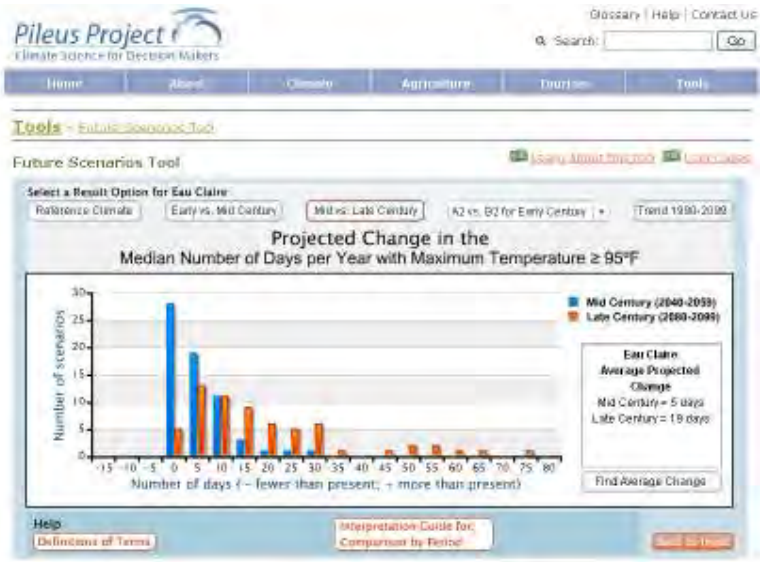


Figure 5. Spatial distribution of the NARCCAP multi-model mean change in the number of days with a maximum temperature greater than 95°F between 2041-2070 and 1971-2000 (top). Climatology of the number of days with a maximum temperature greater than 95°F (bottom). SOURCE: Kunkel et al. 2012

- NARCCAP scenarios suggest to considerable spatial variability
  - 25 day average increase in southern portion of Midwest
  - Fewer than 5 days in northern portion of Midwest
    - Similar in magnitude to Pileus Project scenarios (even though estimated from older GCM simulations



Source: pileus.msu.edu.

Length of Freeze-Free Period

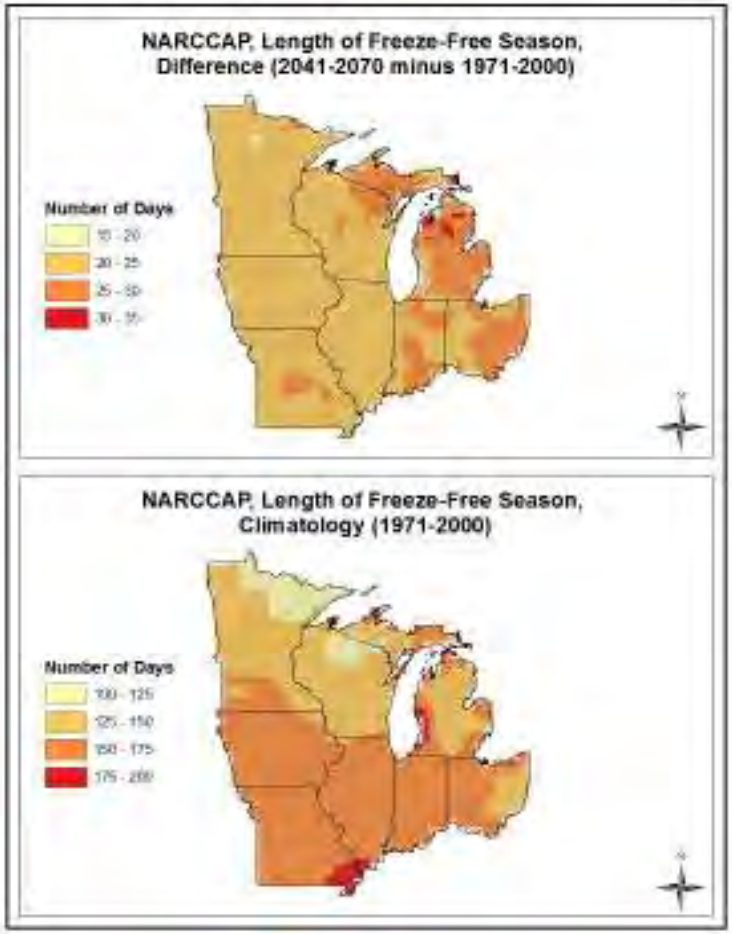
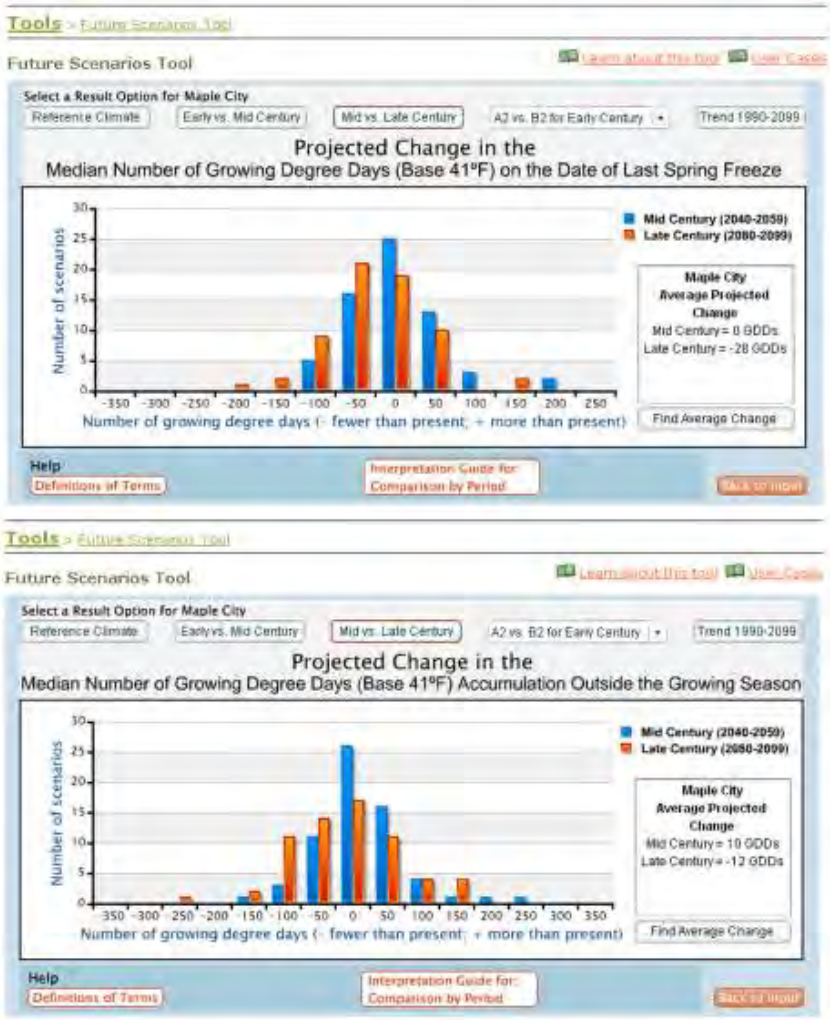


Figure 9. Spatial distribution of the NARCCAP multi-model mean change in the length of the freeze-free season between 2041-2070 and 1971-2000 (top). Climatology of the length of the freeze-free season (bottom).

- NARCCAP
  - Fairly uniform increase across region of 20-25 days by mid century
- Pileus Project
  - Somewhat smaller projected increase of approximately 15 days in Michigan

Freeze Risk

- Projected changes in freeze risk are highly uncertain



Source: pileus.msu.edu.

Annual and Seasonal Precipitation

- Large degree of uncertainty in Midwest precipitation projections
- Ensemble mean of CMIP3 models for end-of-century suggests:
  - Increase in annual and winter precipitation for much of the Midwest, except for western portion
  - Little change or a small decrease in summer
- Over 90% of the 21 models project an increase in winter precipitation in Michigan
- Approximately half of the 21 GCMs projected an increase in summer precipitation in the Midwest by the end of the 21st century and the other half projecting a decrease or no change.

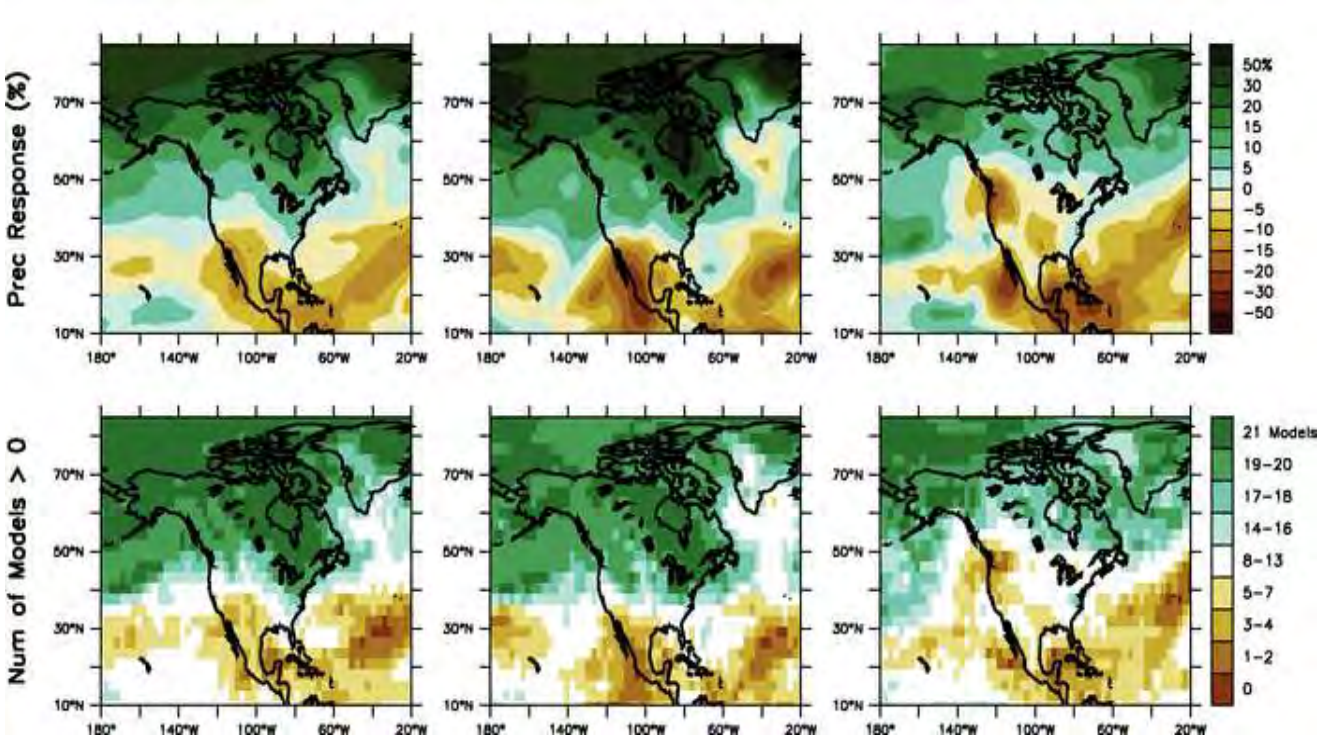


Figure 7. *Temperature and precipitation changes over North America from the MMD-A1B simulations. Top row: annual mean, DJF and JJA precipitation change (in percent) between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Bottom row: number of models out of 21 that project increases in precipitation. SOURCE: Christensen et al. 2007.*

Annual and Seasonal Precipitation

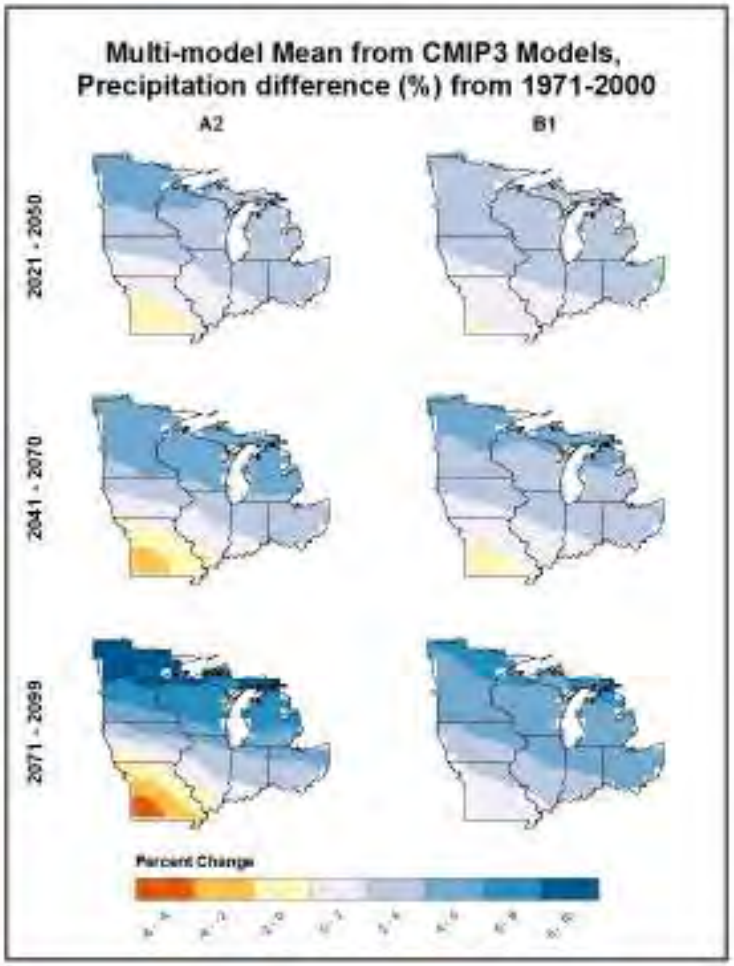


Figure 12. Multi-model mean annual differences in precipitation (%) between the 3 future periods and 1971-2000, from the 15 CMIP3 model simulations. SOURCE: Kunkel et al. 2012

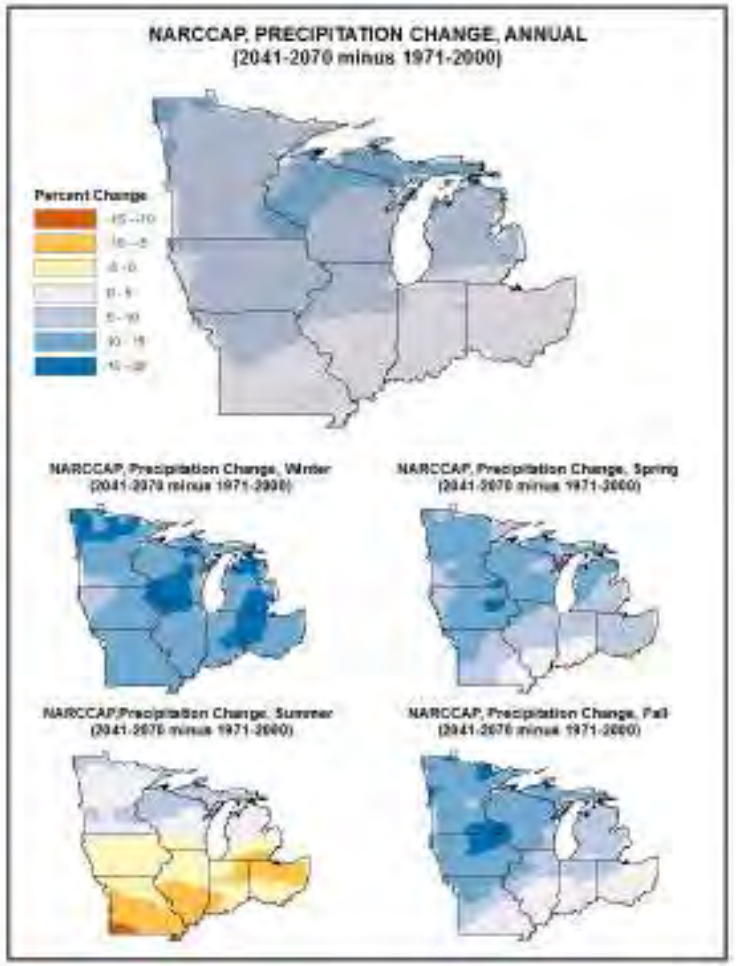


Figure 13. Multi-model mean annual and seasonal differences in precipitation (%) between 2041-2070 and 1971-2000, from the 9 NARCCAP regional climate model simulations. SOURCE: Kunkel et al. 2012

Precipitation Intensity

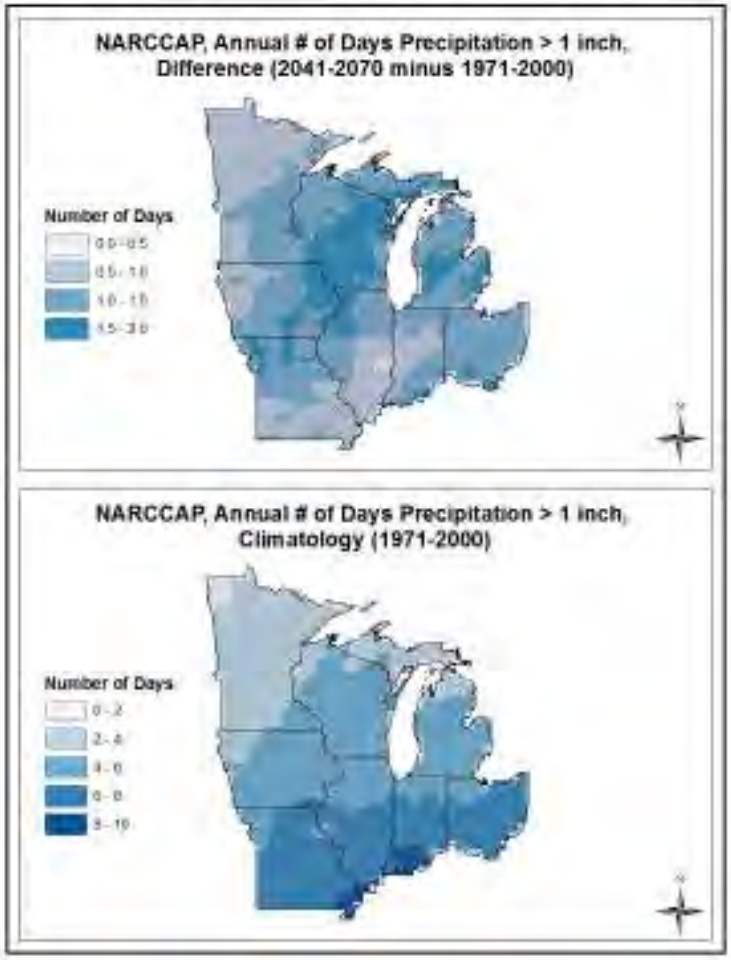


Figure 17. Spatial distribution of the NARCCAP multi-model mean change in the number of days with precipitation exceeding 1 inch between 2041-2070 and 1971-2000 (top). Climatology of the number of days with precipitation exceeding 1 inch (bottom). SOURCE: Kunkel et al. 2012

Wind

- Evaluation of NARCCAP simulations for mid-century displays weak consistency in the climate change signal.
- Current suite of climate projections suggests little change in wind resources or wind extremes to mid-century or longer.

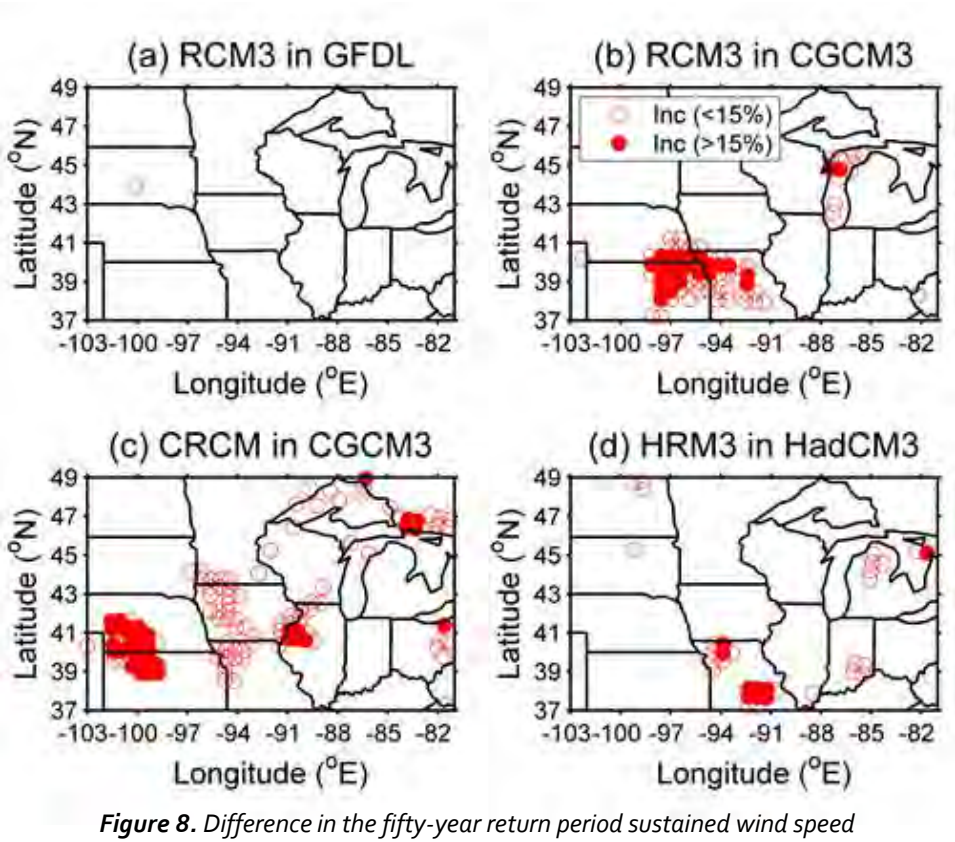


Figure 8. *Difference in the fifty-year return period sustained wind speed (U_{50yr}) over the Midwestern US for 2041-2062 vs. 1979-2000. The frames show the different AOGCM-RCM combinations. The magnitude of change is only shown for grid cells where the value for the future period lies beyond the 95% confidence intervals on the control period. Note; none of the grid cells behind the legend in frame (b) exhibited significant changes. SOURCE: Pryor and Barthelmie (2012b).*

Level of Confidence

- There is no single best climate model or downscaling approach.
- There is greater confidence in projected temperature change than precipitation change.
- In spite of confidence in future warmer temperatures, change in freeze risk remains uncertain.
- The degree of uncertainty surrounding precipitation change remains high, although annual precipitation and precipitation during the cool season are expected to increase, particularly for the eastern portion of the Midwest region.
- There is little confidence in the sign (positive or negative) of change in mean precipitation for the warm season. There is somewhat greater confidence in projections of increases in the frequency and intensity of extreme warm season precipitation events.
- Wind climates, including high impact wind events, remain challenging to simulate with the validity necessary to make assertions regarding the likelihood of change

- Full report available at: http://www.glisa.msu.edu/great_lakes_climate/nca.php