Future Climate Scenarios for Michigan

Symposium on Climate Change Vulnerabilities and Opportunities: Michigan and Beyond

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What is a Scenario?

• A scenario is a plausible future state (Carter et al. 1996).
• In climatology, often referred projections.
• A scenario is not a forecast or a prediction.
General Circulation Models (GCMs)

- Also referred to as Global Climate Models
- Complex, multi-component models

Beneath each time period is a list of the components included in state-of-the-art models such as the NCAR-based Community Climate System Model. (Illustration courtesy Warren Washington, NCAR. ©UCAR.)
Structure of CCSM 3.0

[Diagram showing the structure of CCSM 3.0, including atmospheric processes like incoming solar energy, outgoing heat energy, transition from solid to vapor, evaporative and heat energy exchanges, and cloud formation. Also includes land surface processes such as precipitation, evaporation, runoff, soil moisture, and oceanographic processes like currents, temperature, salinity, and ocean bottom topography.]
Figure SPM-1: Schematic illustration of SRES scenarios. Four qualitative storylines yield four sets of scenarios called "families": A1, A2, B1, and B2. Altogether 40 SRES scenarios have been developed by six modeling teams. All are equally valid with no assigned probabilities of occurrence. The set of scenarios consists of six scenario groups drawn from the four families: one group each in A2, B1, B2, and three groups within the A1 family, characterizing alternative developments of energy technologies: A1FI (fossil fuel intensive), A1B (balanced), and A1T (predominantly non-fossil fuel). Within each family and group of scenarios, some share "harmonized" assumptions on global population, gross world product, and final energy. These are marked as "HS" for harmonized scenarios. "OS" denotes scenarios that explore uncertainties in driving forces beyond those of the harmonized scenarios. The number of scenarios developed within each category is shown. For each of the six scenario groups an illustrative scenario (which is always harmonized) is provided. Four illustrative marker scenarios, one for each scenario family, were used in draft form in the 1998 SRES open process and are included in revised form in this report. Two additional illustrative scenarios for the groups A1FI and A1T are also provided and complete a set of six that illustrate all scenario groups. All are equally sound.
Ensemble Approach

- Multiple scenarios are used to estimate the “quantifiable range of uncertainty”.

Source: IPCC, 2001
**Figure SPM.5.** Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios. The assessment of the best estimate and likely ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}
Figure SPM.6. Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999. The central and right panels show the AOGCM multi-model average projections for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over the decades 2020–2029 (centre) and 2090–2099 (right). The left panels show corresponding uncertainties as the relative probabilities of estimated global average warming from several different AOGCM and Earth System Model of Intermediate Complexity studies for the same periods. Some studies present results only for a subset of the SRES scenarios, or for various model versions. Therefore the difference in the number of curves shown in the left-hand panels is due only to differences in the availability of results. SOURCE: IPCC AR4 Working Group I report.
Figure SPM.7. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. SOURCE: IPCC AR4 Working Group I Report
Figure 11.12. Temperature and precipitation changes over North America from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation. SOURCE: IPCC AR4 Working Group I report
Downscaling

• Local/regional effects not captured well in GCM simulations
  – e.g., impact of Great Lakes
• GCM simulations not always in terms of regional-relevant variables
  – e.g., lake levels
• Dynamic vs Empirical Downscaling
  – Regional climate models (RCMs)
  – Statistical relationships
Climate Scenarios from the Pileus Project

www.pileus.msu.edu
Scenario Requirements

- Local scale
- Daily temporal resolution
- Multiple locations in Michigan and the surrounding area
- Maximum temperature, minimum temperature, wet/dry day, liquid precipitation
- Need to be expressed in terms of industry relevant parameters (e.g., thresholds, spells)
- GCM based

- Scenarios for 1990-2099 desirable with a particular focus on three 20-year time slices.
  - Early Century (2010-2029)
  - Mid Century (2040-2059)
  - Late Century (2080-2099)

- Ensemble of scenarios is required to estimate uncertainty
- Web-based tool for decision makers (www.pileus.msu.edu)
• 15 Locations
• 4 GCMs
  • CCC CGCM2
  • HadCM3
  • MPI ECHAM4
  • NCAR CSM1.2
• 2 Emission scenarios
  • A2, B2
• Multiple empirical downscaling methodologies

>60 scenarios for each climate variable per location

A2, B2
multiple downscaling methodologies

NCAR
ECHAM
Canadian
Hadley
A2, B2
multiple
downscaling
methodologies

Hadley

ECHAM

Canadian

>60 scenarios for each climate variable per location

2000+ daily temperature and precipitation scenarios for 1990-2100
Projected Temperature Changes

- Some examples for Eau Claire, Michigan
Projected Change in the Median Length of the Growing Season

Number of days (− shorter than present; + longer than present)

Early Century (2010-2029)
Mid Century (2040-2059)

Eau Claire Average Projected Change
Early Century = 7 days
Mid Century = 15 days

Find Average Change

Help
Definitions of Terms

Interpretation Guide for: Comparison by Period

Back to Input
Projected Change in the Median Number of Growing Degree Days (Base 41°F) during the Frost-Free Season

**Eau Claire**
Average Projected Change
- Early Century = 149 GDDs
- Mid Century = 390 GDDs

Find Average Change
Projected Change in the Median Number of Days per Year with Maximum Temperature ≥ 95°F

Eau Claire
Average Projected Change
Early Century = 2 days
Mid Century = 5 days

Find Average Change
Percentage of local minimum temperature scenarios suggesting an **INCREASE** in interannual variability at the annual scale compared to a 1990-2019 control period for 30-year overlapping periods. The scenarios were constructed by interpolating the GCM-simulated temperature series (based on the A2 greenhouse gas emissions scenario) to station locations. Results for a given period are shown for the last year of the 30-year period – e.g. results for 1990-2019 are presented in the graph at year 2019.

(From Guentchev, Piromsopa, and Winkler, 2009)
AN APPLICATION: Projected Change in the Median Day of the Year of Side Green for Tart Cherries in NW Michigan
Global Climate Change Impacts in the United States,
www.globalchange.gov/usimpacts
Changing Summers

Model projections of summer average temperature and precipitation changes in Illinois and Michigan for midcentury (2040-2059), and end-of-century (2080-2099), indicate that summers in these states are expected to feel progressively more like summers currently experienced in states south and west. Both states are projected to get considerably warmer and have less summer precipitation. SOURCE: Global Climate Change Impacts in the United States, www.globalchange.gov/usimpacts
Plant winter hardiness zones in the Midwest have already changed significantly as shown above, and are projected to shift one-half to one full zone every 30 years. In the graphic, each zone represents a 10°F range in the lowest temperature of the year, with zone 3 representing –40 to –30°F and zone 8 representing 10 to 20°F. SOURCE: Arbor Day Foundation
Average Great Lakes levels depend on the balance between precipitation (and corresponding runoff) in the Great Lakes Basin on one hand, and evaporation and outflow on the other. As a result, lower emissions scenarios with less warming show less reduction in lake levels than higher emissions scenarios. Projected changes shown here are for a higher emissions scenario.

SOURCE: Global Climate Change Impacts in the United States, www.globalchange.gov/usimpacts
Future Developments

• Hybrid dynamic-empirical scenarios for Michigan
  – North American Regional Climate Change Assessment Program (NARCCAP)
    • Regional climate model simulations
    • 50 km resolution
    • Multiple GCMs/RCMs
    • A2 emission scenario
  – Empirical downscaling applied
    • Local scale scenarios
    • “de-biasing” (including validation for Michigan)
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