THE SCIENCE OF GLOBAL CLIMATE CHANGE:
How Climate Change May Affect Minnesota’s Ecosystems

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WHAT MAY HAPPEN TO MINNESOTA’S CLIMATE?

HOW MAY CHANGES IN CLIMATE AFFECT MINNESOTA’S ECOSYSTEMS?
WELCOME TO LAKE SUPERIOR?
MINNESOTA CLIMATE...

CLIMATE is the prevailing weather conditions of a region averaged over long periods of time.
Typical jet stream
Jet stream during the second week of July 2014: loopy and not as organized

Jet stream during the first week of January 2014: again contorted farther south
Go home, Arctic, You’re Drunk.

Posted by Greg Laden on January 5, 2014.

GO HOME, ARCTIC

YOU'RE DRUNK
meanwhile in the rest of the world…

Land & Ocean Temperature Departure from Average Jan 2014
(with respect to a 1981–2010 base period)
Data Source: GHCN–M version 3.2.2 & ERSST version 3b
Climate change in Minnesota: Ice out

Lake Calhoun

- Ice out in 1950: April 22
- Spring 2011: April 10
- Spring 2012: March 18
- Spring 2014: April 20
- Spring 2015: April 1
Climate change in Minnesota: Snowfall

- Average snowfall in Duluth = 86.1 inches
- Total for 1995-96 = 135.4"
- Total for 2013-14 = 129.6"
- Total for 2014-2015: 49.2"
Climate change in Minnesota: Extreme floods

Duluth, June 17-20, 2012: 9 inches of rain in 30 hours
Climate change in Minnesota: Tornadoes

- **2010:** Greatest number of tornadoes
  - In a year = 113
  - In a month = 71
  - In a day = 48
    (June 17)

- **2013:** 15 tornadoes

Near Willmar, MN 2010
MINNESOTA CLIMATE:

CLIMATE is the prevailing weather conditions of a region averaged over long periods of time.
A BIOME is a large land area characterized by a prevailing CLIMATE that supports a major ecological community type.

...AND THE BIOMES THAT RESULT:
Minnesota is unique in that it supports three major biomes, making it a grand ECOTONE... a transition zone between biomes.
Where Goes the Climate, so Goes the Biomes...
TEMPERATURE
(Solar Radiation)

PRECIPITATION
(Amount & Timing)

SOIL MOISTURE
(Evapotranspiration)
CLIMATE & BIOME PATTERNS

[Diagram showing various biomes and their patterns across the map of North America, including Tundra, Coniferous Forest, Boreal Forest, Montane Forest, Desert, Grassland, Chaparral, and Tropical Forest.]
GLOBAL BIOMES “SURVIVE & THRIVE”

Annual Precipitation (cm)

Average Temperature (°C)

Tropical Rain Forest

Temperate Rain Forest

Tropical Seasonal Forest

Temperate Deciduous Forest

Savanna

Temperate Grassland and Desert

Subtropical Desert

Taiga

Tundra

U.S.

Whittaker Biome Diagram

Originally from RH Whittaker
Communities and Ecosystems
1975: (Robert)

Modified from RE Ricklefs
The Economy of Nature
2000
Tolerance Limits

- Zone of intolerance
  - Species absent
  - Too low: lower limit of tolerance

- Zone of physiological stress
  - Species infrequent
  - Optimum

- Optimal range
  - Species abundant

- Zone of physiological stress
  - Species infrequent
  - Too high: upper limit of tolerance

- Zone of intolerance
  - Species absent

Environmental Gradient
Average Annual Temperature (U.S.)
“Survive & Thrive” Tolerance Ranges

-20°F  0°F  30°F  41°F  60°F  80°F

-14°F  Boreal Forest  60°F
30°F  40°F  Deciduous  72°F
10°F  Grassland  80°F

J. Corney
U.S. Average Temperatures
**TEMPERATURE**

**Sub-Tropical**
- U.S.: -12-27°C (10-80°F)

**Sub-Tropical Temperate**
- U.S.: 2-22°C (35-72°F)

**Boreal**
- U.S.: -26-16°C (-14-60°F)

**Sub-Arctic**
- U.S.: -26-16°C (-14-60°F)
U.S. Average Precipitation
SOIL MOISTURE

U.S. Estimated Water Budget

- Evapotranspiration: 67%
- Surface Runoff: 29%
- Consumptive Use: 2%
- Groundwater Outflow: 2%

Evapotranspiration = transpiration + evaporation

Wikipedia

USGS
U.S. “Pan” Evaporation Rates
(a rough measure of Potential Evapotranspiration)
SOIL MOISTURE

Ecotone

W

E

S

J.Corney
NORTH AMERICA’S PRAIRIE-FOREST BORDER
WHAT IS MINNESOTA’S CURRENT CLIMATE?
(Averaged over the past 120 years)

TEMPERATURE: 41°F annual avg.
PRECIPITATION: 26 in. annual avg.
TEMPERATURE ISOLINES

NWS
PRECIPITATION ISOLINES

NWS

PRECEPITATION

22in

26in

34in

NWS
**Isoline Convergence Point**

- **Temperature**
  - 41°F
  - 44°F

- **Precipitation**
  - 22in
  - 26in
  - 34in

- **Minnesotan Biomes**
  - Coniferous Forest
  - Deciduous Forest
  - Grassland

- **Sources**
  - NWS
  - MN DNR
CURRENT
MN CLIMATE
OF 2015

Whittaker Biome Diagram
Originally from RH Whittaker
Communities and Ecosystems
1975;
Modified from RE Ricklefs
The Economy of Nature
2000

26in. (66cm)
Average Temperature (°C)
0 10 20 30
0 100 200 300 400
Annual Precipitation (cm)

41°F (5°C)
HAVE THERE BEEN CHANGES IN MINNESOTA’S CLIMATE?
HAVE THERE BEEN CHANGES IN MINNESOTA’S CLIMATE?
Have there been changes in Minnesota’s climate?
TRIPLE-BIOME CONVERGENCE POINT (1900-1930)

Average Annual Temperature Isoclines (°F)

Average Annual Precipitation Isoclines (inches)

19 in  23 in  26 in  31 in  34 in

1900-1930

1930

St. Cloud Area

NWS adapted by C. Lehman
Average Annual Temperature Isoclines (°F) vs. Average Annual Precipitation Isoclines (inches)

TRIPLE-BIOME CONVERGENCE POINT (1930-2010)

- Detroit Lakes Area

NWS adapted by C. Lehman
MINNESOTA BIOMES

About a 100 mile shift
WHAT MAY HAPPEN TO MINNESOTA’S FUTURE CLIMATE?
**TEMPERATURE**

3.5 – 4.0°C  
(6.3 – 7.2°F)  
**INCREASE**  

5°C (41°F) Current Avg.  
becomes  
9°C (48°F) Predicted Avg.

**PRECIPITATION**

5 – 10%  
(1.3 – 2.6 in.)  
**INCREASE**  

26 in. Current Avg.  
becomes  
28 in. Predicted Avg.

IPCC, 2007
Extreme heat, heavy downpours, and flooding will affect infrastructure, health, agriculture, forestry, transportation, air and water quality, and more. Climate change will also exacerbate a range of risks to the Great Lakes.

Explore how climate change is affecting the Midwest.
MORE PRECIPITATION

BUT... SUMMERS MAY BE MUCH DRIER THAN CURRENT CONDITIONS.

The maps show projected future changes in precipitation relative to the recent past as simulated by 15 climate models. The simulations are for late this century, under a higher emissions scenario. For example, in the spring, climate models agree that northern areas are likely to get wetter, and southern areas drier. There is less confidence in exactly where the transition between wetter and drier areas will occur. Confidence in the projected changes is highest in the hatched areas.
Temperatures expected to increase more in winter than in summer
US Pond Hockey Championship, Lake Nokomis
TRIPLE-BIOME CONVERGENCE POINT (2010-2100)

Average Annual Temperature Isoclines (°F)

Average Annual Precipitation Isoclines (inches)

NWS adapted by C. Lehman

Oh, Canada!
PREDICTED MN CLIMATE OF 2100

Whittaker Biome Diagram
Originally from RH Whittaker
Communities and Ecosystems
1975;
Modified from RE Ricklefs
The Economy of Nature
2000

28 in. (71 cm)

26 in.

41°F

48°F (9°C)
WHERE GOES THE CLIMATE, SO GOES THE BIOMES.
So, Maybe Not This...
Perhaps something like this…

Cedar Creek
So, How Will the Trees Migrate?
DISTURBANCE, SUCCESSION & COMPETITION
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East Bethel, MN 55005
(612) 301-2602
spive007@umn.edu
### LUVERNE, MN US

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<th>SEASON</th>
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### EMBARRASS, MN US

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### MINNEAPOLIS ST PAUL INTERNATIONAL AIRPORT, MN US

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<td>39.4</td>
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<td>57.0</td>
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### FOREST LAKE 5 NE, MN US

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<td>Autumn</td>
<td>8.23</td>
<td>35.8</td>
<td>47.0</td>
<td>58.1</td>
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**Heat Energy “Drives” Evapotranspiration**

- **Diagram:**
  - At low temperature, water molecules have low average KE.
  - At high temperature, water molecules have high average KE.

- **Graph:**
  - Shows water vapor pressure by temperature.
  - The graph illustrates the increase in water vapor pressure as temperature increases.
Plant Adaptations in North America (MN)

**Coniferous Trees**
(cold, dry climates)
- Needles reduce moisture loss
- Evergreen - able to photosynthesize at low temperatures
- Conical shape gives the tree stability
- Thick covering of needles - slow decomposition in cold climate
- Permafrost in higher latitudes
- Wide roots to anchor tree in thin soil

**Deciduous Trees**
(warm, moist climates)
- Broad leaves increase light gathering potential
- Canopy branches spread out to maximize exposure to sunlight
- Thick trunk supports tall tree crown as attempt to grow above all other plants
- Extensive surface roots to gather water and nutrients from decomposing litter
- Large taproot to support large tree and reach steady water supply
- Leaves wither and drop off tree during fall/winter months, ceasing photosynthesis until leaves regrow in the spring/summer

**Grasses**
(warm, dry climates)
- Narrow leaves and stems bend easily and reduce moisture loss
- Long, fibrous roots to reach water, and allow grass to store nutrients during winter and survive above-ground burning

A. Stacey

Image credit: Dogtooth Design
SUSTAINABILITY ISSUES

The Concern!

Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii

Global Temperatures
- Annual Average
- Five Year Average

IPCC
**SUSTAINABILITY ISSUES**

Natural vs. Man Made Influences

**Comparison between modeled and observed temperature since 1860**

- **Natural causes**
  - After 1950, the temperature rise cannot be explained by natural causes alone.

- **Man made causes**
  - This temperature increase cannot be explained by human activity alone.

- **Natural and man made causes**
  - The model that includes man made and natural causes is the best fit.

**Best Match!**
Energy Flow

Earth’s Energy Budget

16% Absorbed by greenhouse gases and emitted to space
3% Absorbed by clouds and emitted to space
6% Back scattered by air
20% Reflected by clouds

51% Absorbed by water and land
21% Infrared radiation emitted from Earth’s surface
7% Sensible heat
23% Latent heat energy
Surface to Atmosphere Energy Transfer

Radiation, conduction, and convection move energy from place to place.

暖気:
- 分子が動きやすくなります。
- 分子が遠くに離れています。
- 暖かい空気は密度が低いです。
- 暖かい空気は比熱が大きいです。

冷気:
- 分子が動き遅くなります。
- 分子は密に詰められています。
- 冷たい空気は密度が大きいです。

放射:
- 太陽光が地面を温めます。

伝導:
- 地面が暖かい空気を温めます。

対流:
- 冷たい密な空気が下降し、暖かい空気を押し出します。暖かい空気はエネルギーを上方に持つ。
Energy Moves Back thru Atmosphere
More Carbon Dioxide in Atmosphere

Same timeframe for each scenario.