Climate Change Research in Northeastern US and Eastern Canadian Forest Ecosystems

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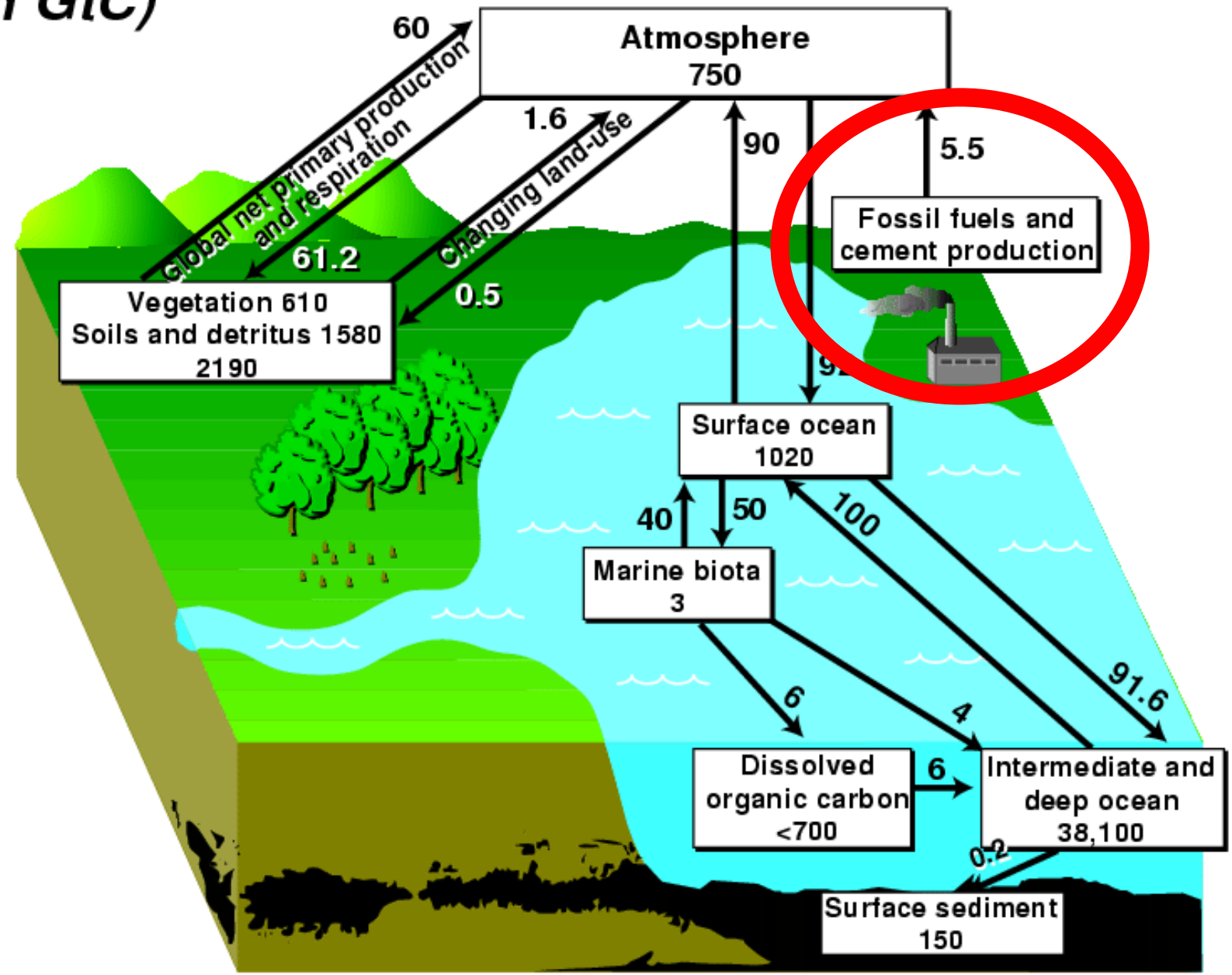
USDA Forest Service
October 26, 2005, Albany New York

Overview

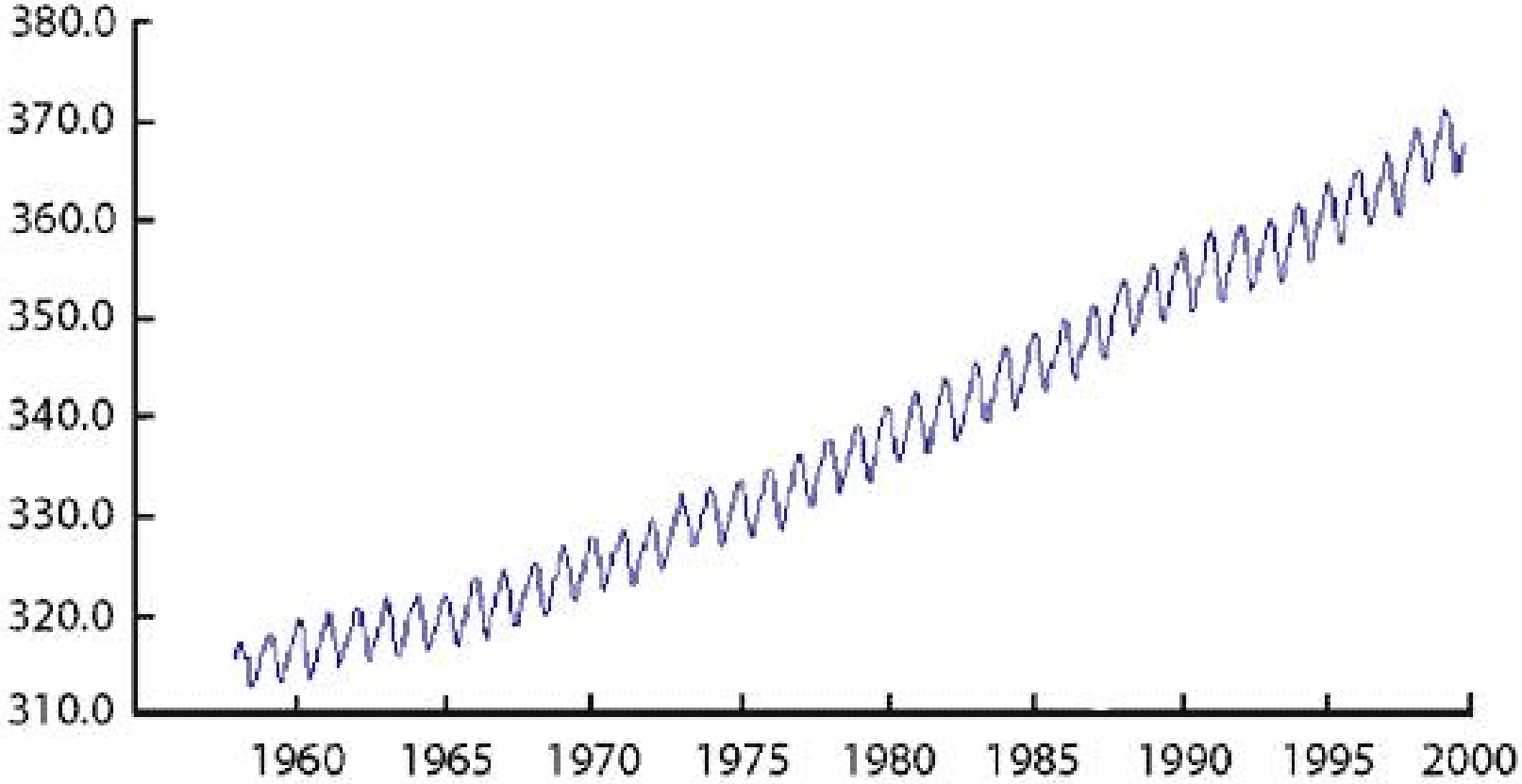
- Set the Stage – Climate Change
- Overview of Regional Research
- A New Synthesis and Outreach Project

Global Carbon Cycle

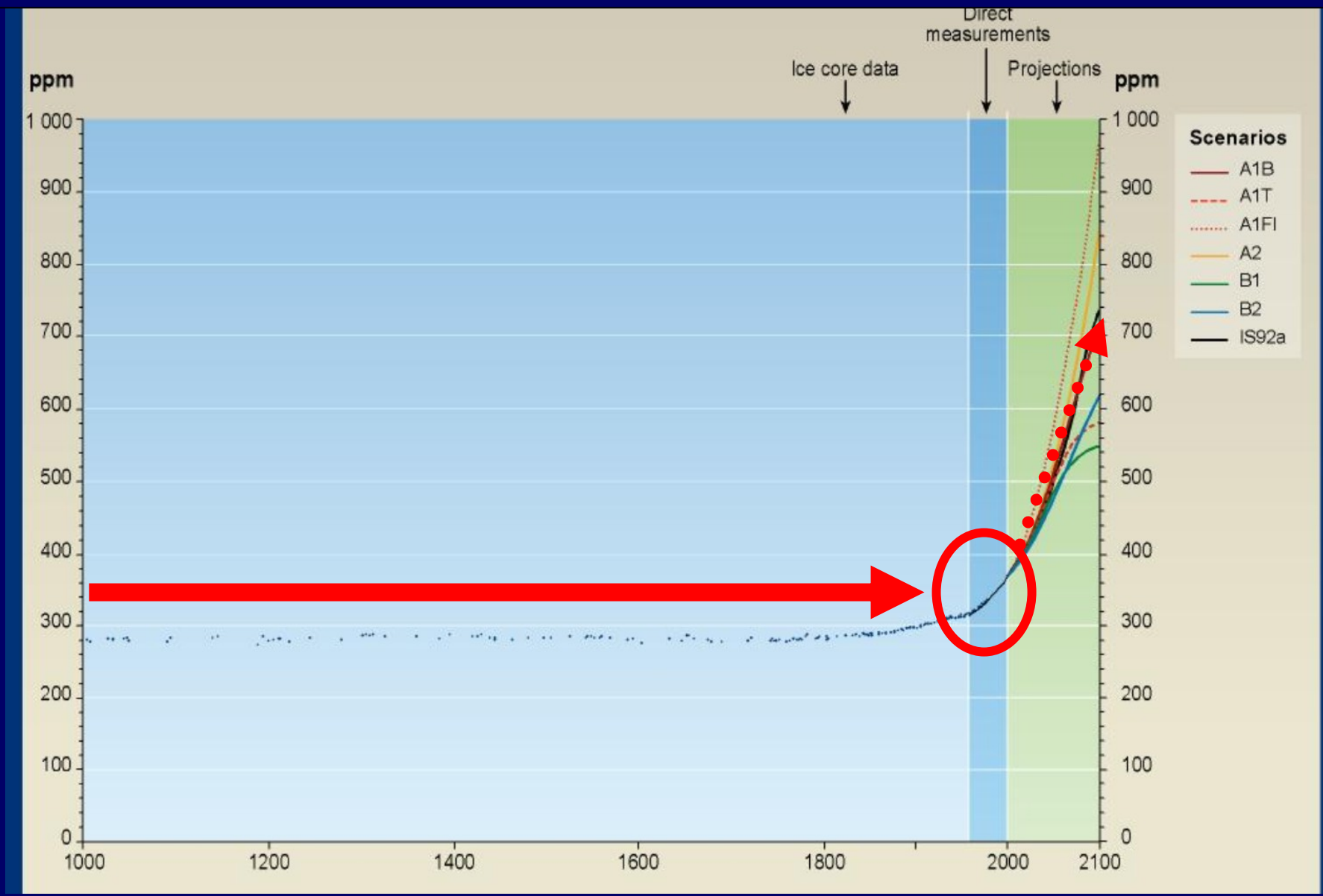
(in GtC)



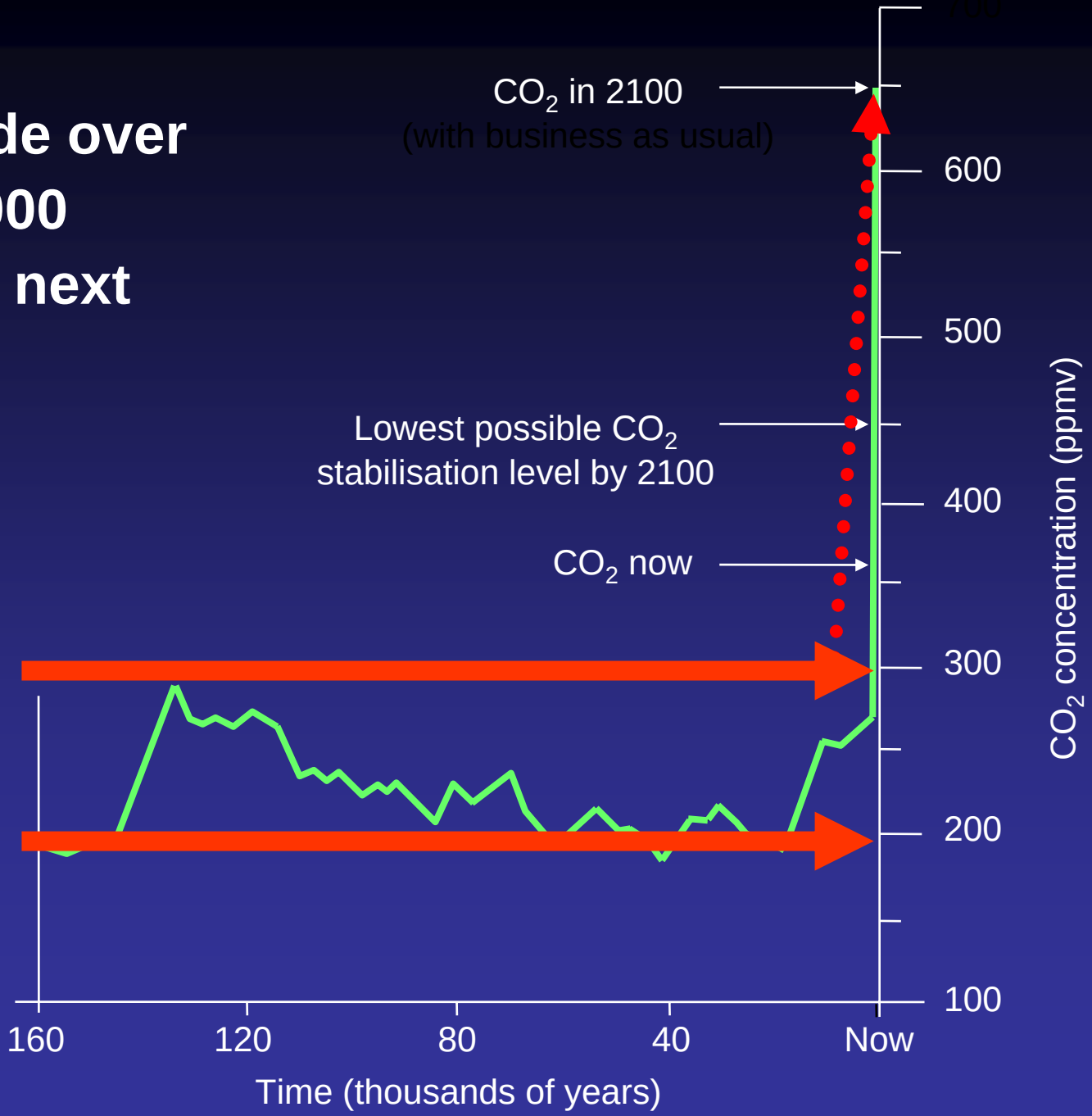
Keeling Curve



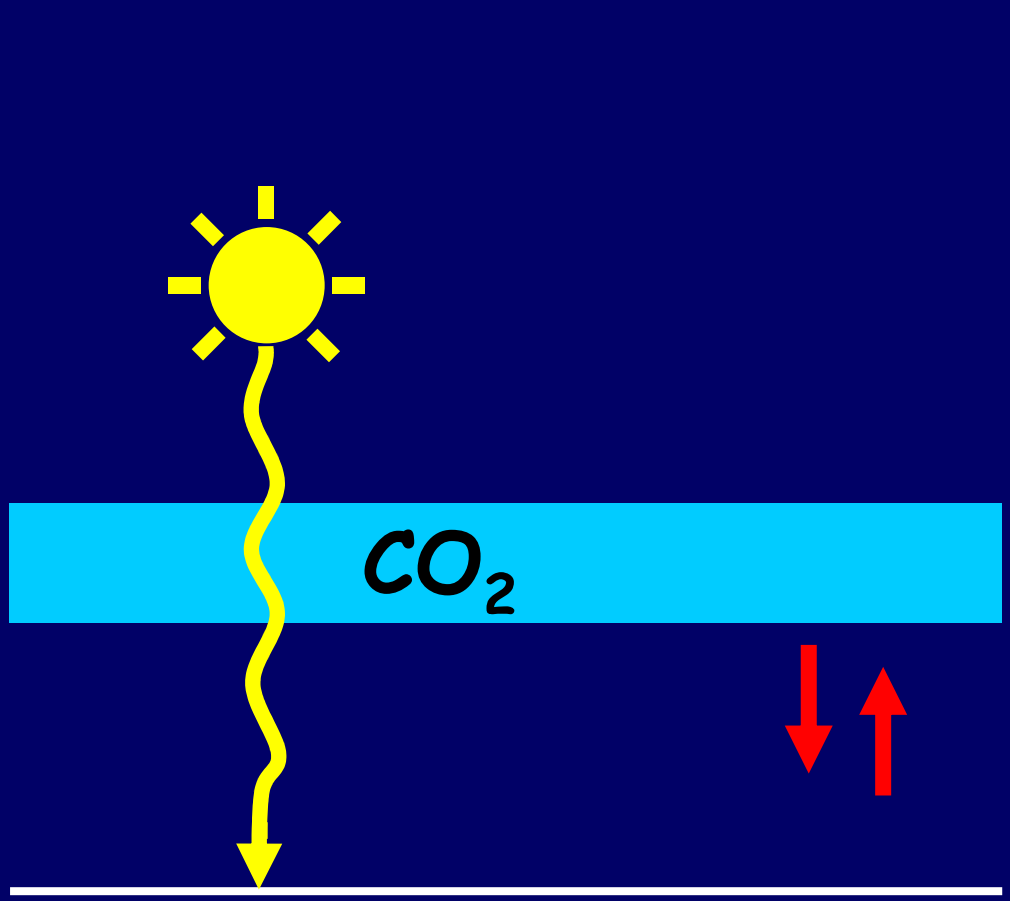
Atmospheric Carbon Dioxide Over the Last 1000 Years

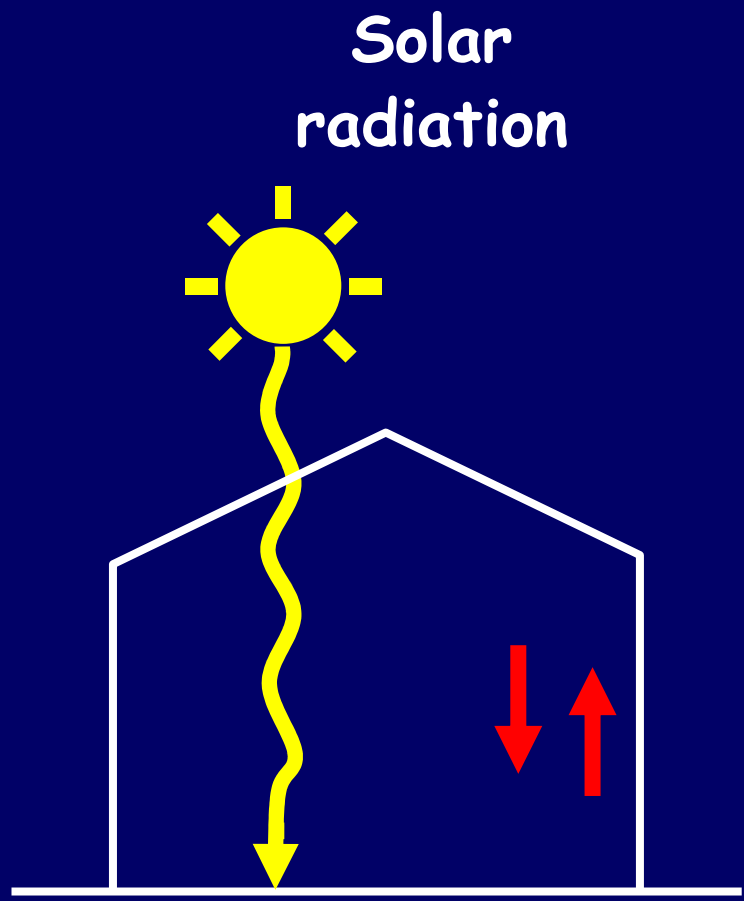


Atmospheric Carbon Dioxide over the last 160,000 years and the next 100 years

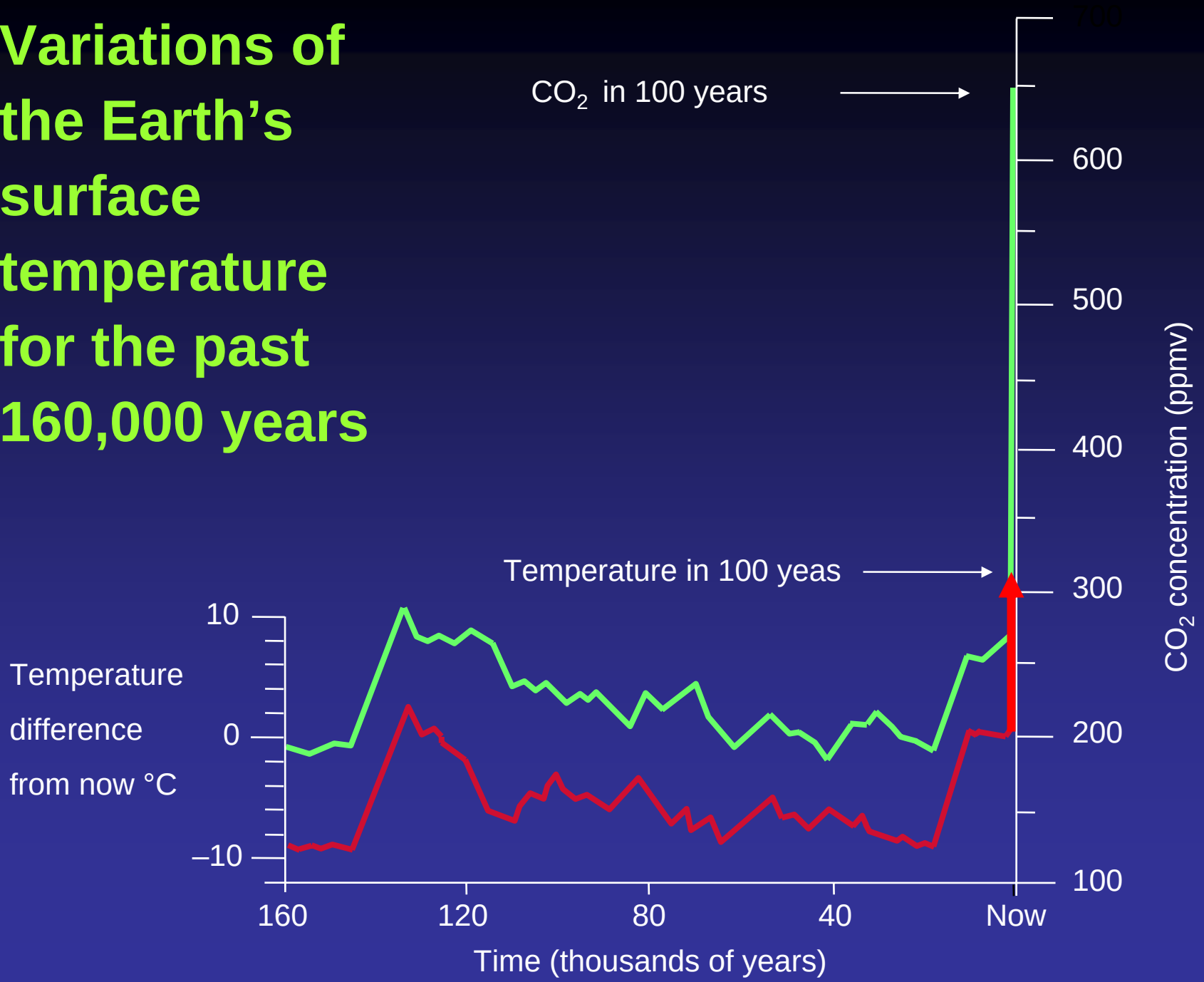


The Greenhouse Effect





Variations of the Earth's surface temperature for the past 160,000 years



Climate has changed globally….

- ✓ 0.6°C increase in global mean temperature
- ✓ Change in magnitude and distribution of precipitation

(IPCC, 2001)

Climate has changed regionally…

- ✓ 0.4°C increase in mean annual temperature
- ✓ 4 - 20% increase in mean annual precipitation
- ✓ Increased variability in both temperature and precipitation

(NERA, 2001)

Indicators of Climate Change

(Tom Huntington et al.)

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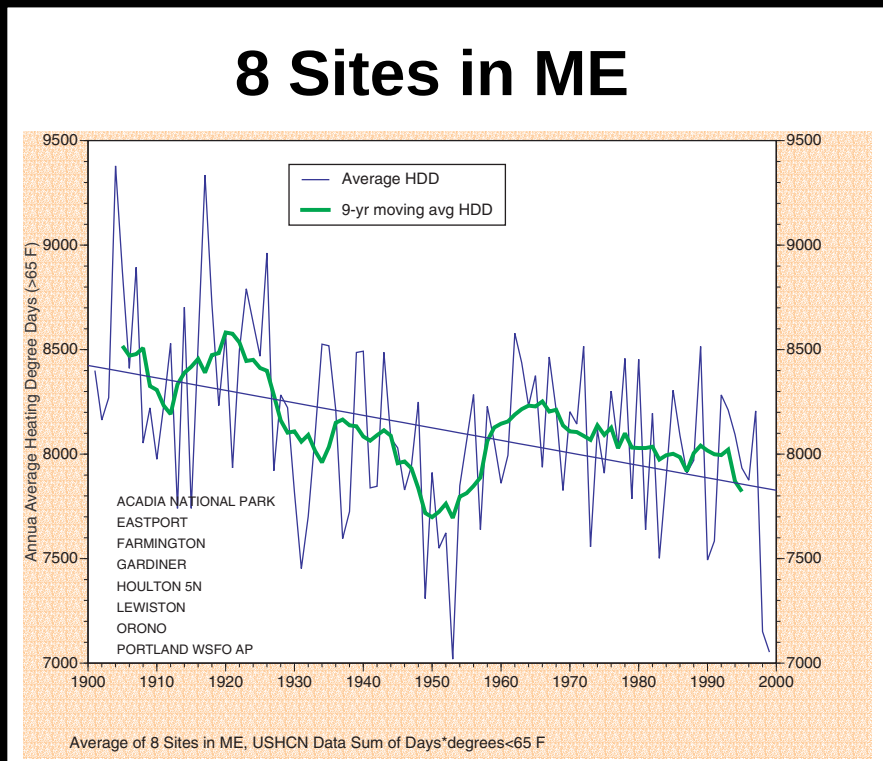
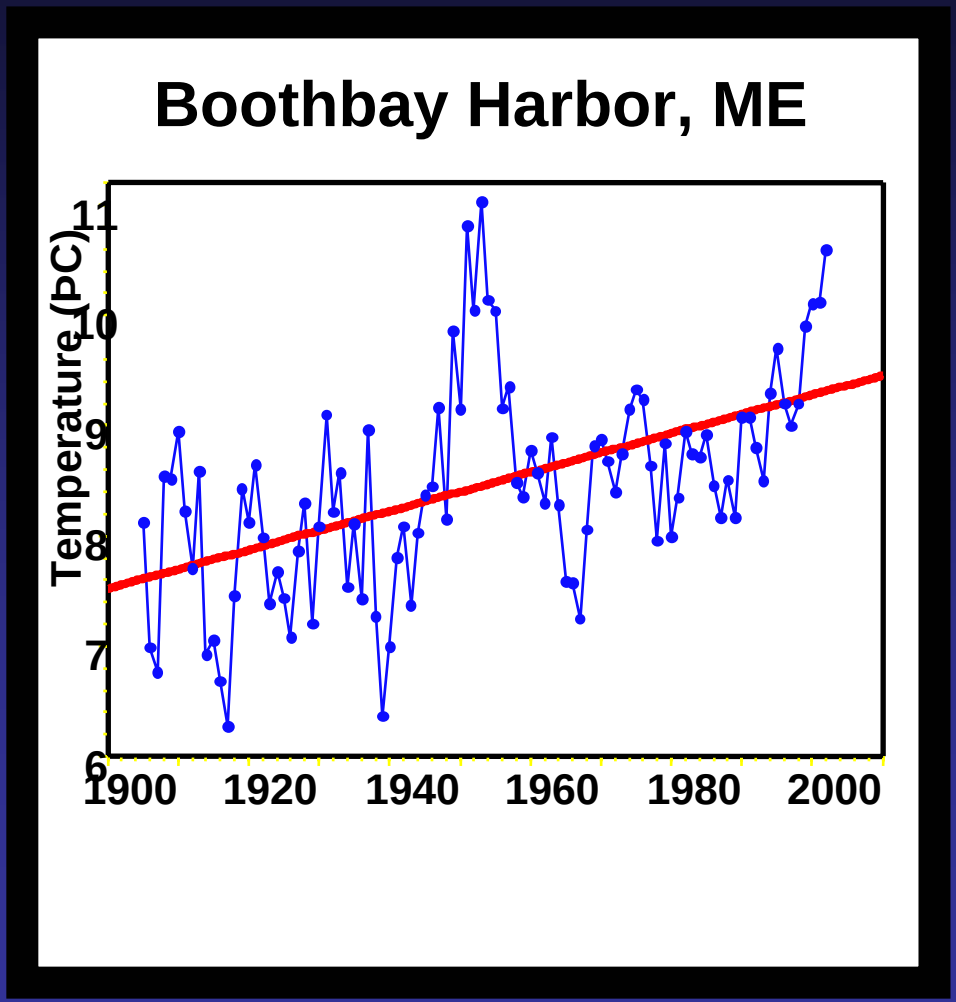
(Tom Huntington et al.)



- **Heating Degree Days**

Indicators of Climate Change

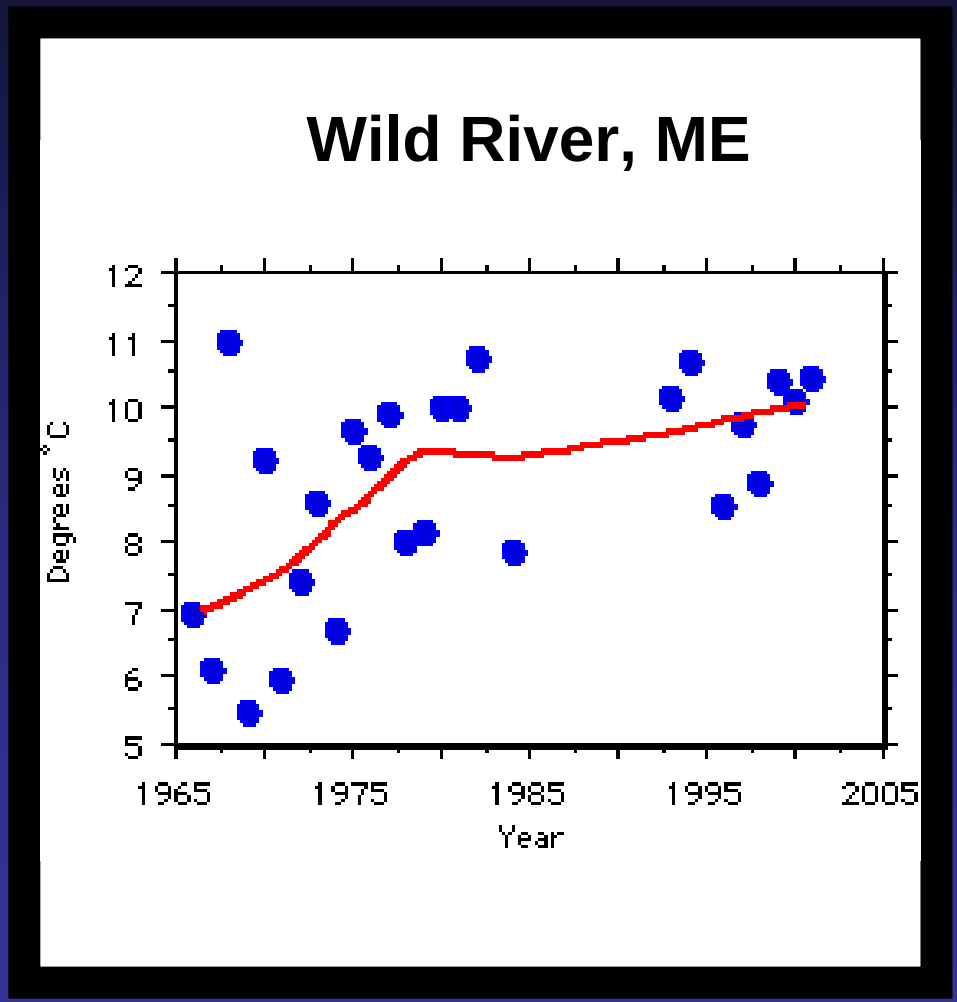
(Tom Huntington et al.)



- **Heating Degree Days**
- **Mean Annual Sea Surface Temperature, Boothbay Harbor, Me**

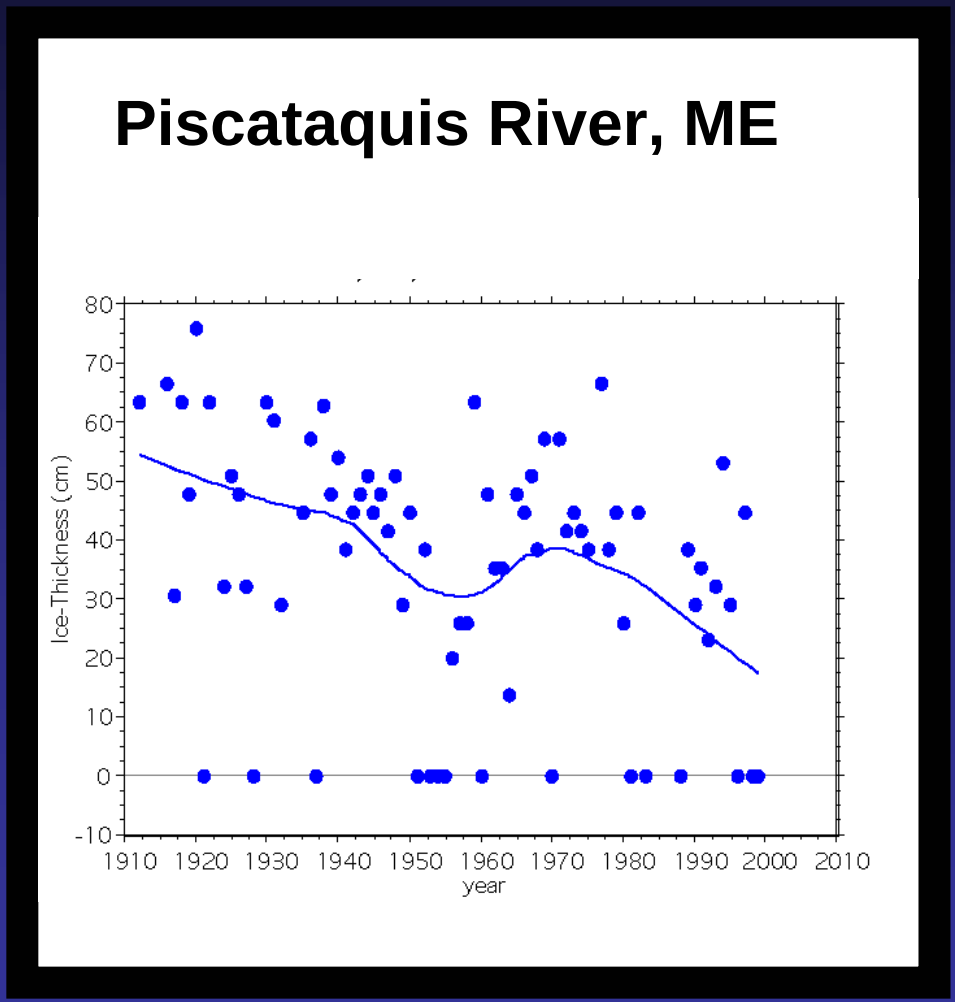
Indicators of Climate Change

(Tom Huntington et al.)



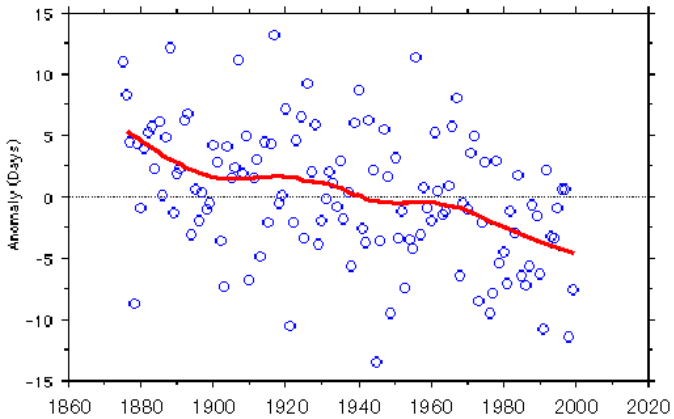
- **Heating Degree Days**
- **Mean Annual Sea Surface Temperature, Boothbay Harbor, ME**
- **Water Temperature at the Wild River, ME**

Indicators of Climate Change
(Tom Huntington et al.)



- Heating Degree Days
- Mean Annual Sea Surface Temperature, Boothbay Harbor, ME
- Water Temperature at the Wild River, ME
- **Ice Thickness, Piscataquis River, ME**

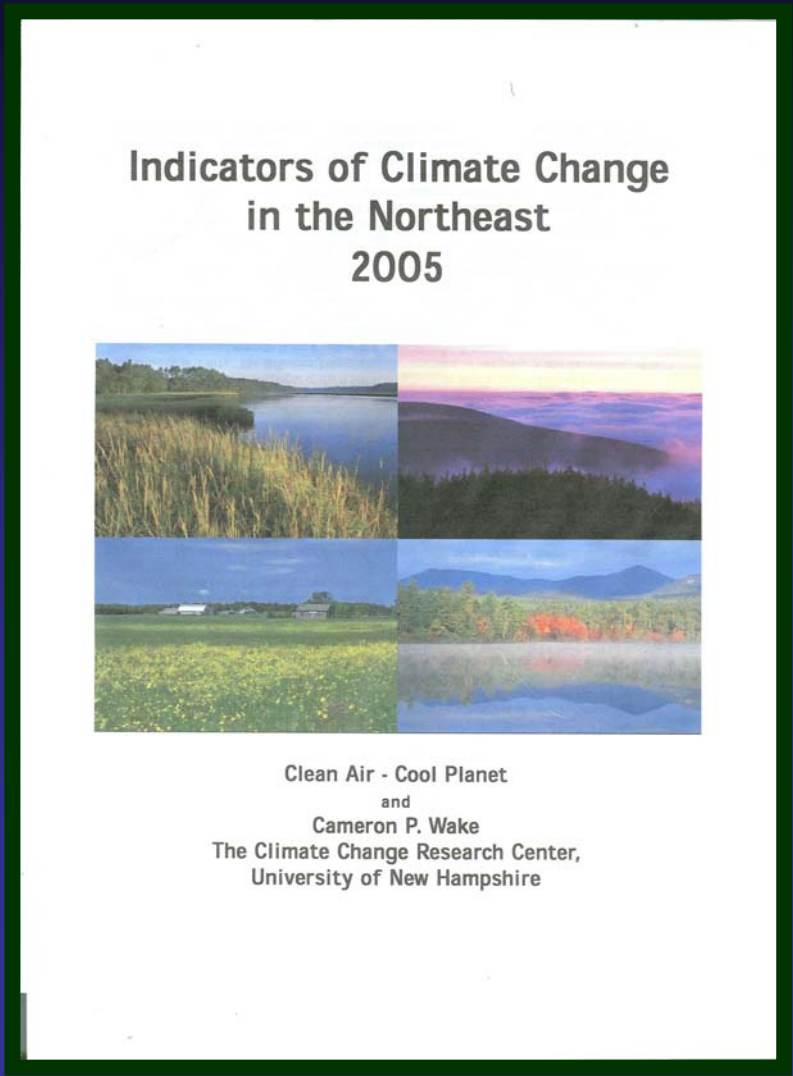
Indicators of Climate Change
(Tom Huntington et al.)



Schwartz, M. D. and B. E. Reiter. 2000. Changes in North American spring. International Journal of Climatology 20:929-932.

- Heating Degree Days
- Mean Annual Sea Surface Temperature, Boothbay Harbor, ME
- Water Temperature at the Wild River, ME
- Ice Thickness, Piscataquis River, ME
- **Day of first bloom, Lilac, NE USA**

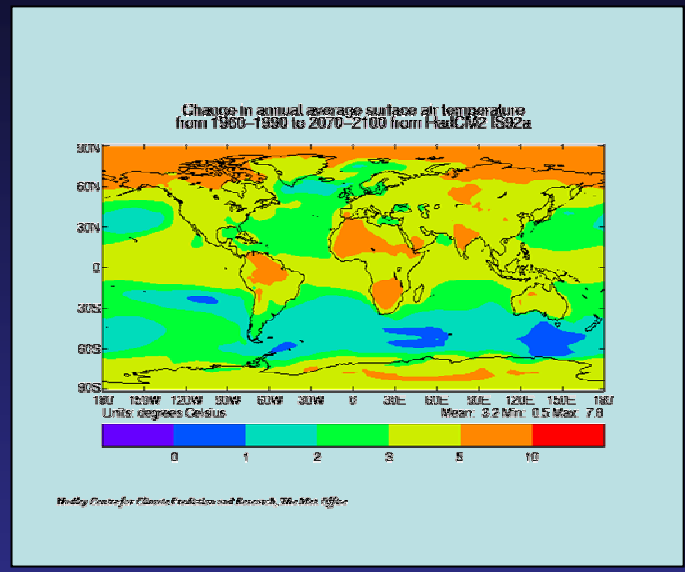
Clean Air/Cool Plant



Climate will continue to change globally….

Climate will continue to change globally….

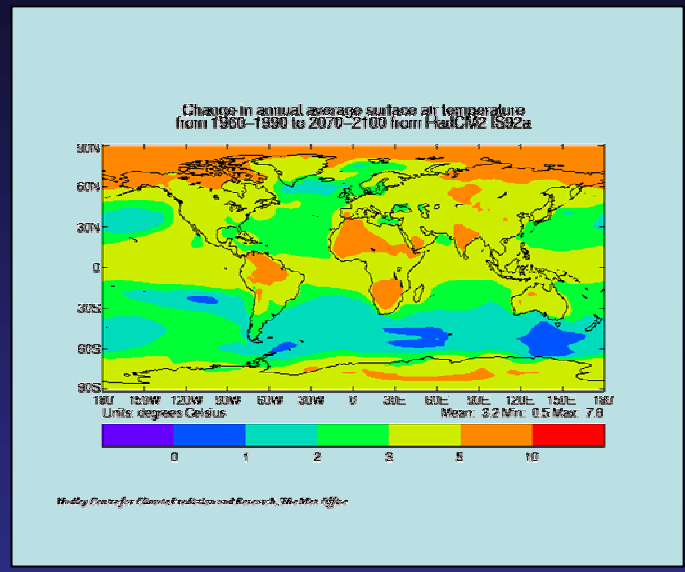
- ✓ **1.4 to 5.8 ^{o}C increase in mean annual temperature**

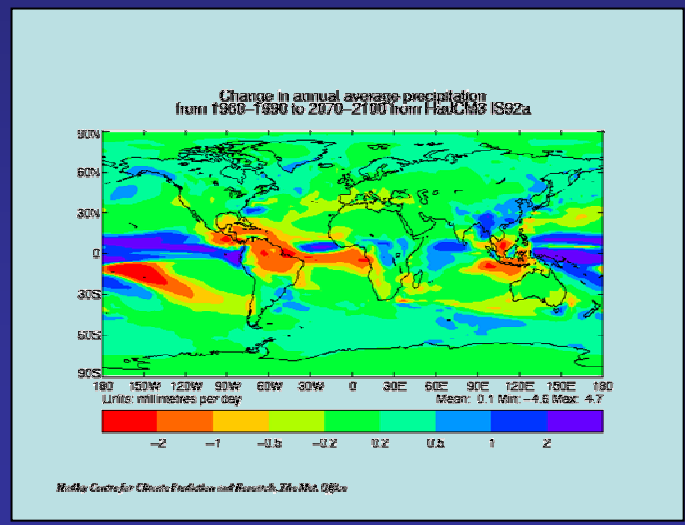


(IPCC, 2001)

Climate will continue to change globally….

- ✓ **1.4 to 5.8 ^{o}C increase in mean annual temperature**
- ✓ **Change in quantity and distribution of precipitation**



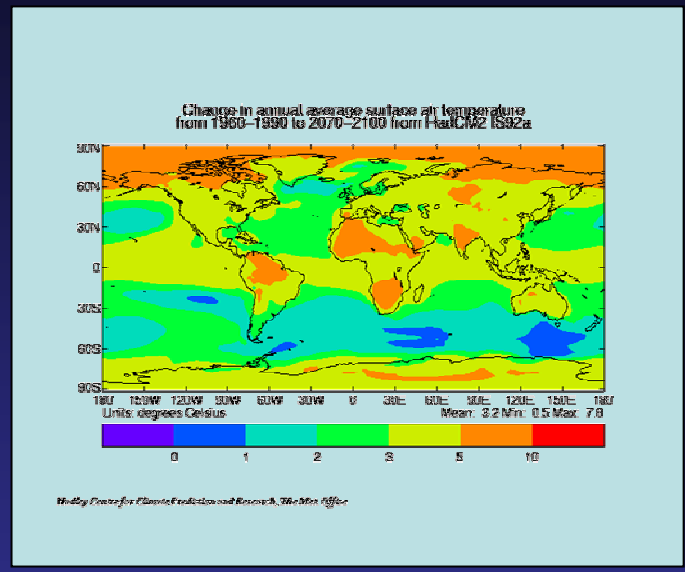


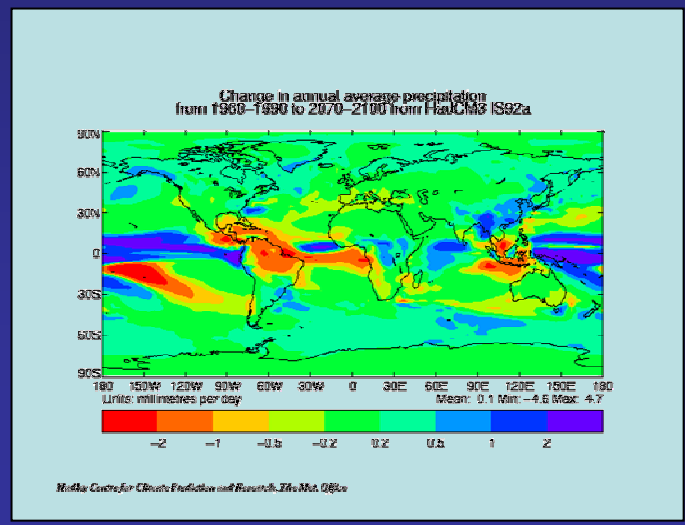
(IPCC, 2001)

Climate will continue to change globally….

- ✓ **1.4 to 5.8 ^{o}C increase in mean annual temperature**
- ✓ **Change in quantity and distribution of precipitation**
- ✓ **Increased frequency and magnitude of severe weather events including droughts, floods, and *HURRICANES!***

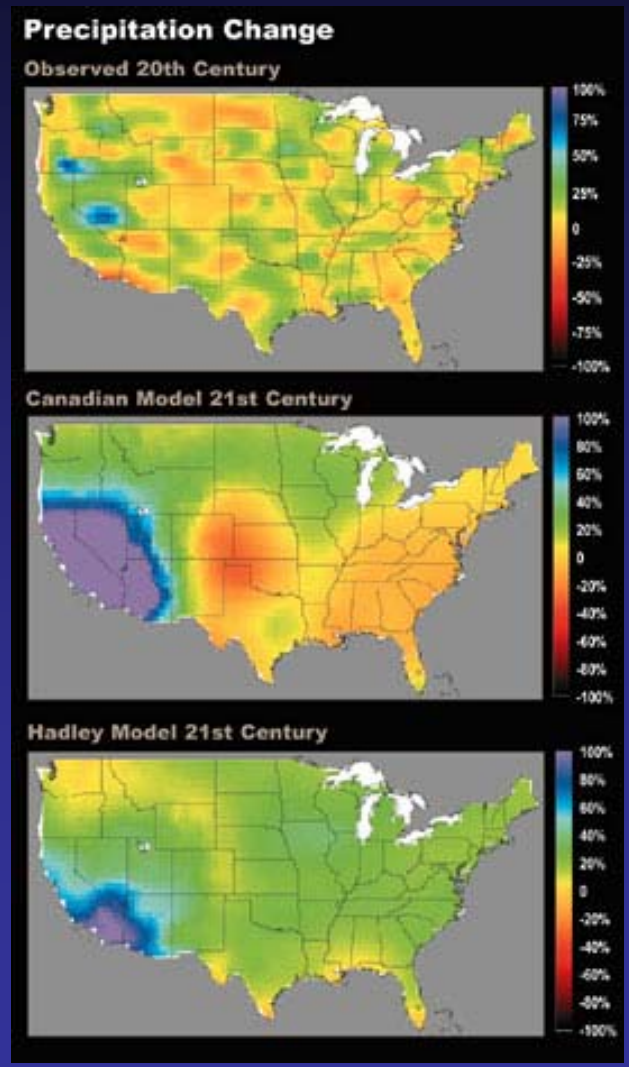
(IPCC, 2001)





Climate will continue to change regionally….

- ✓ 3.1 to 5.3ºC increase in mean annual temperature
- ✓ 10-30% increase in precipitation
- ✓ Increased frequency of drought (Canadian Model)
- ✓ Greater intra- and inter-annual climate variability

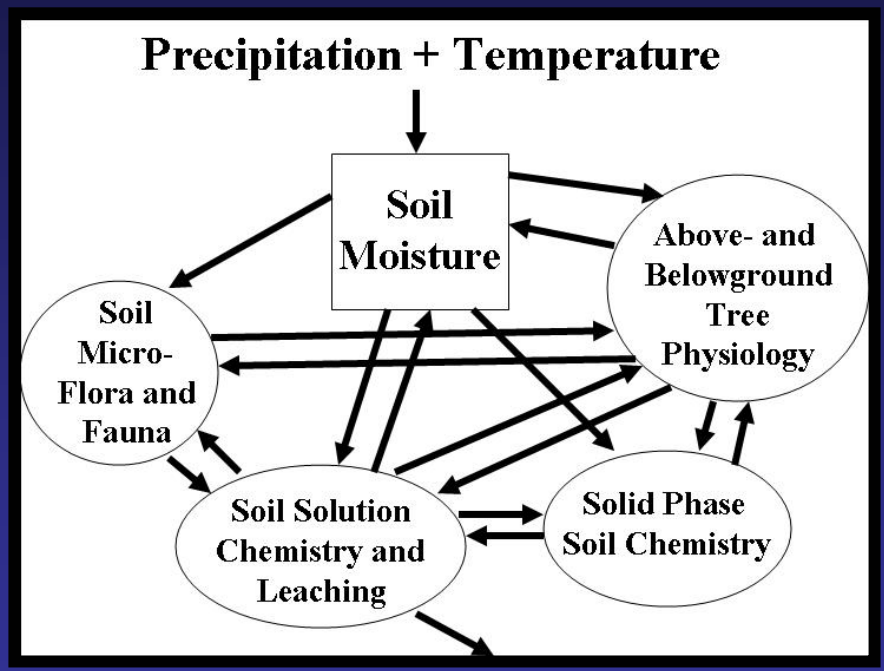


(NERA, 2001)

So what?

So what?

Temperature and moisture are two of the fundamental drivers of all chemical and biological processes



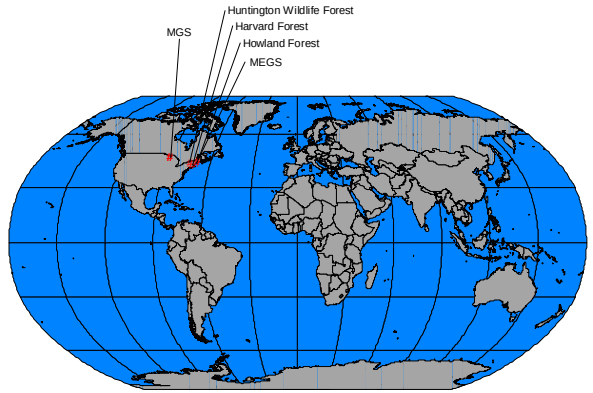
The Research

- Experimental Manipulations
- Gradients
- Biological Observations
- Modeling

Experimental Manipulations

- **Temperature**

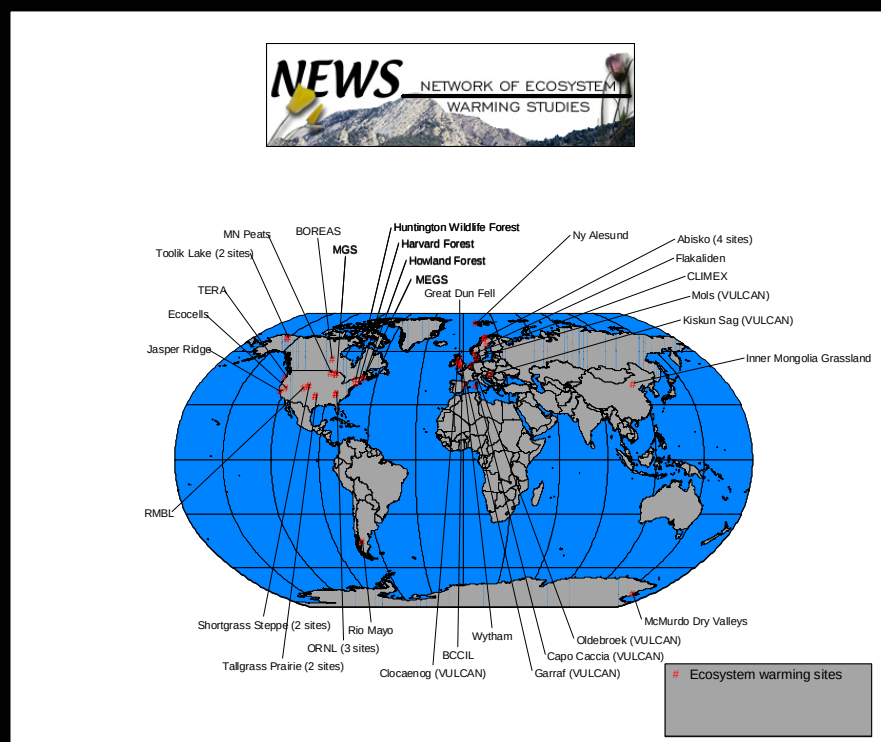
Regional Synthesis



Rustad, L.E., J.M.Melillo, M.J. Mitchell, I. J. Fernandez, P. A. Steudler, and P. J. McHale 2000. Effects of soil warming on C and N cycling in Northern U.S. forest soils. In: Mickler, R., R. Birdsey, and J. Hom (eds.).pp.357-381. Responses of Northern U.S. Forests to Environmental Change. Springer-Verlag New York Inc.

Experimental Manipulations

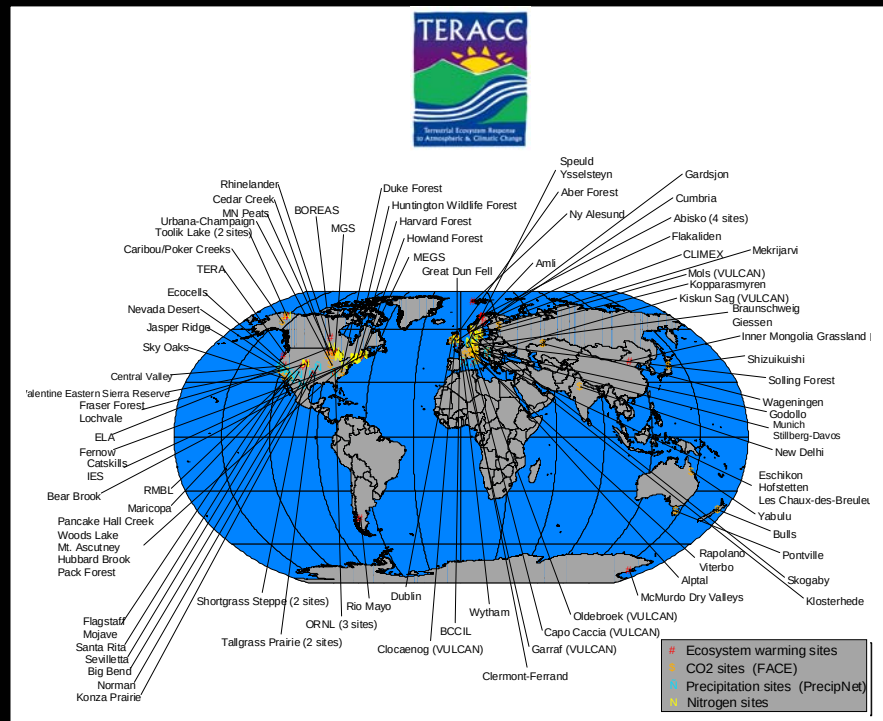
- **Temperature**



Rustad, L.E., J. Campbell, G.M. Marion, R.J. Norby, M.J. Mitchell, A.E. Hartley, J. H.C. Cornelissen, J. Gurevitch, GCTE-NEWS. 2001. A Meta-analysis of the response of soil respiration, net N mineralization, and aboveground plant growth to experimental ecosystem warming. Oecologia 126: 543-562.

Experimental Manipulations

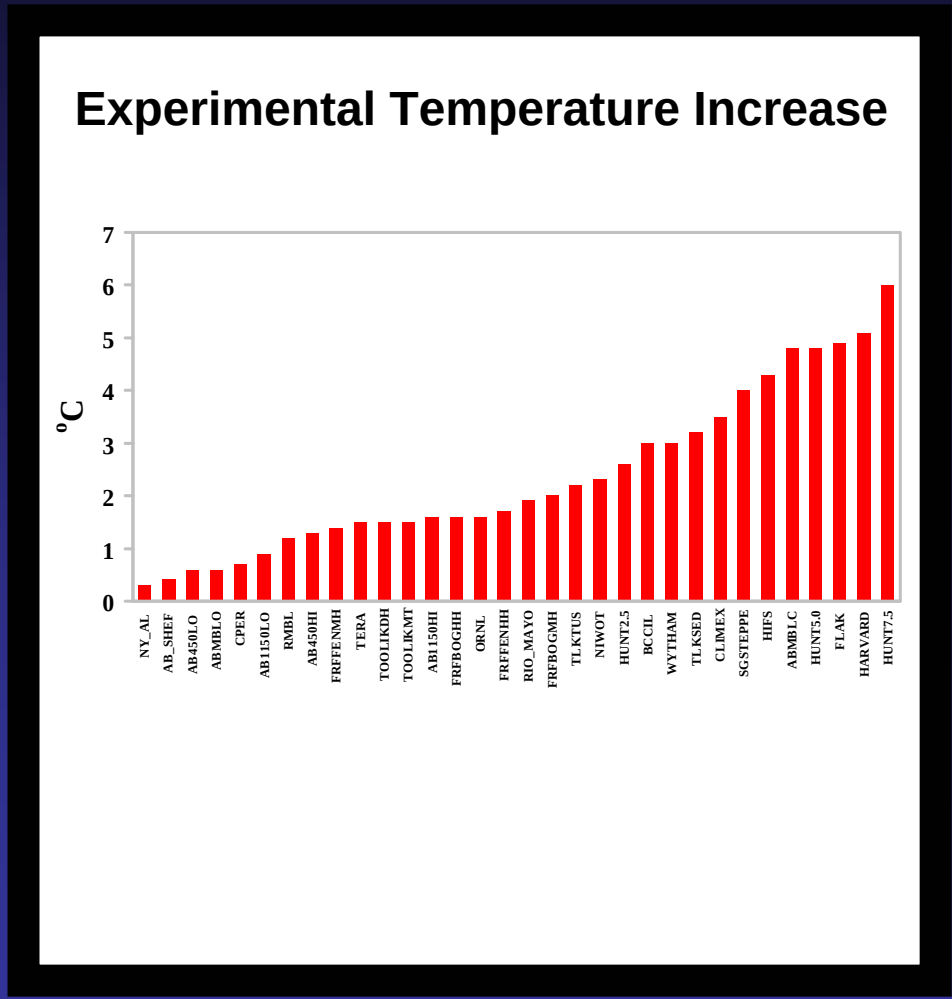
- **Temperature**



20 peer-reviewed papers
1 book
2 book chapters

Experimental Manipulations

- **Temperature**



Experimental Manipulations

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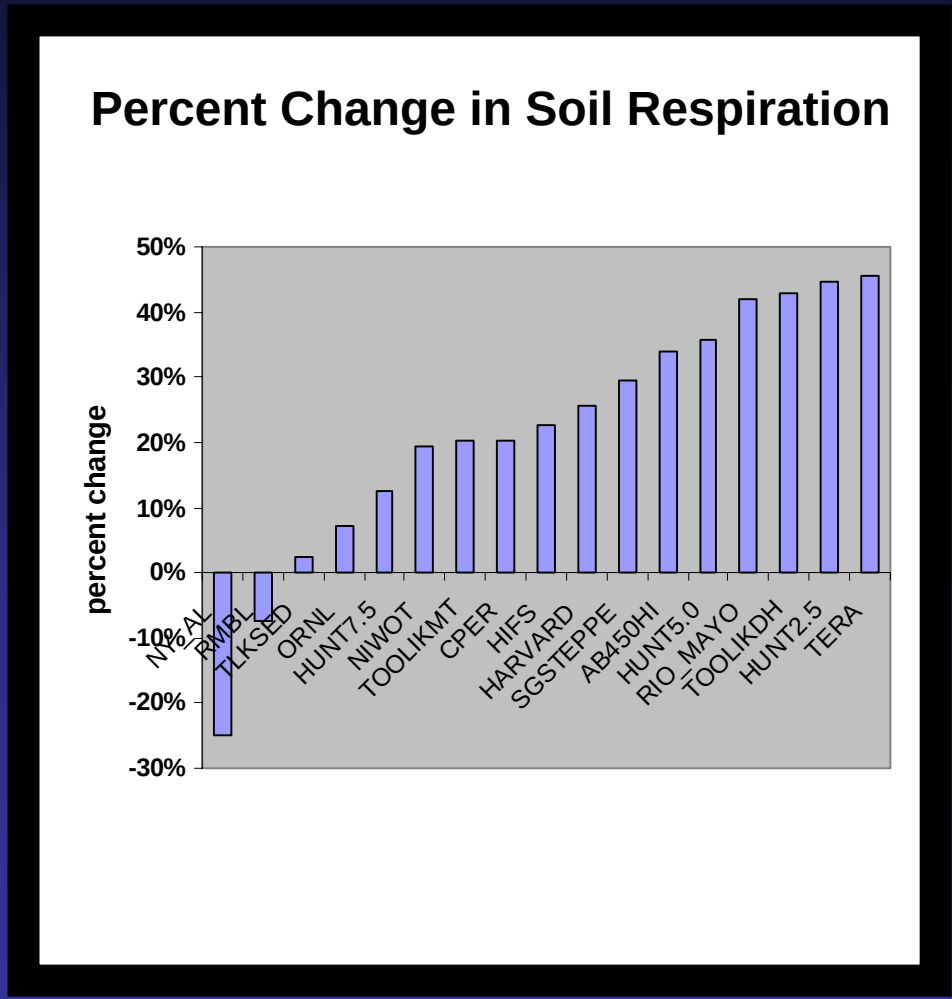

Experimental Manipulations

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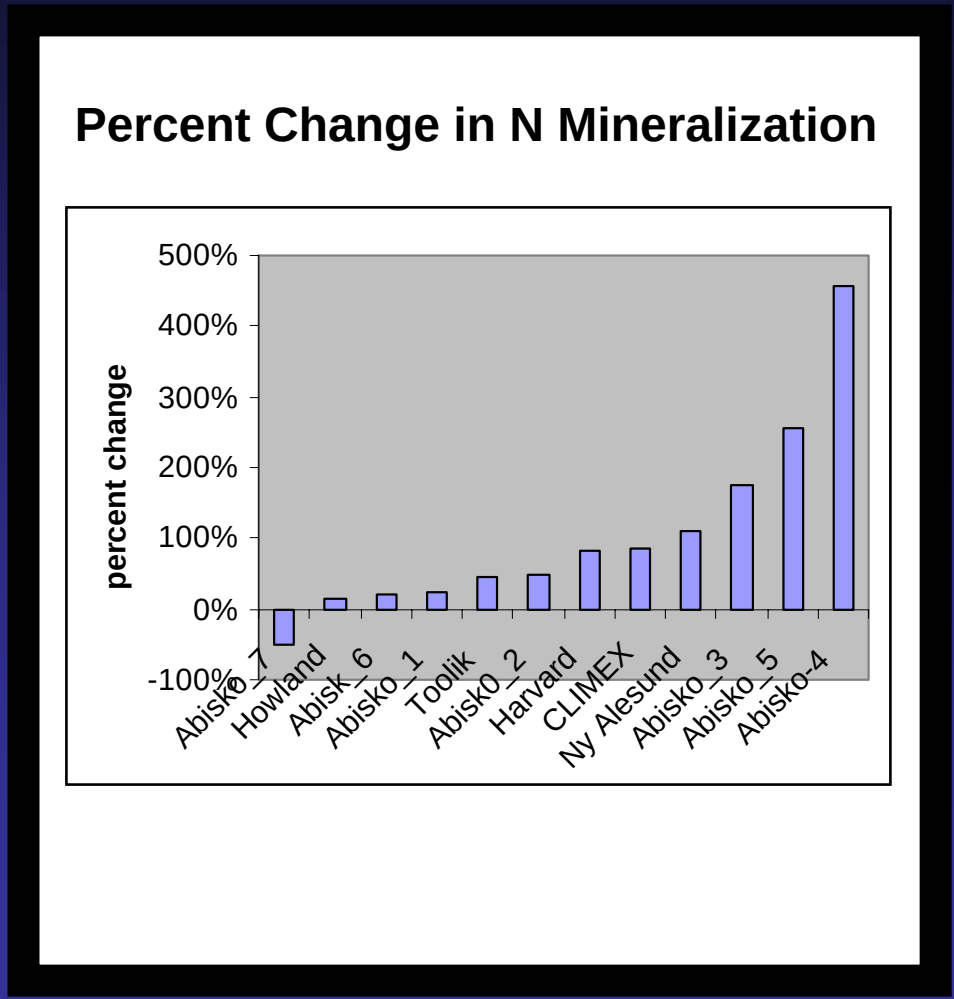

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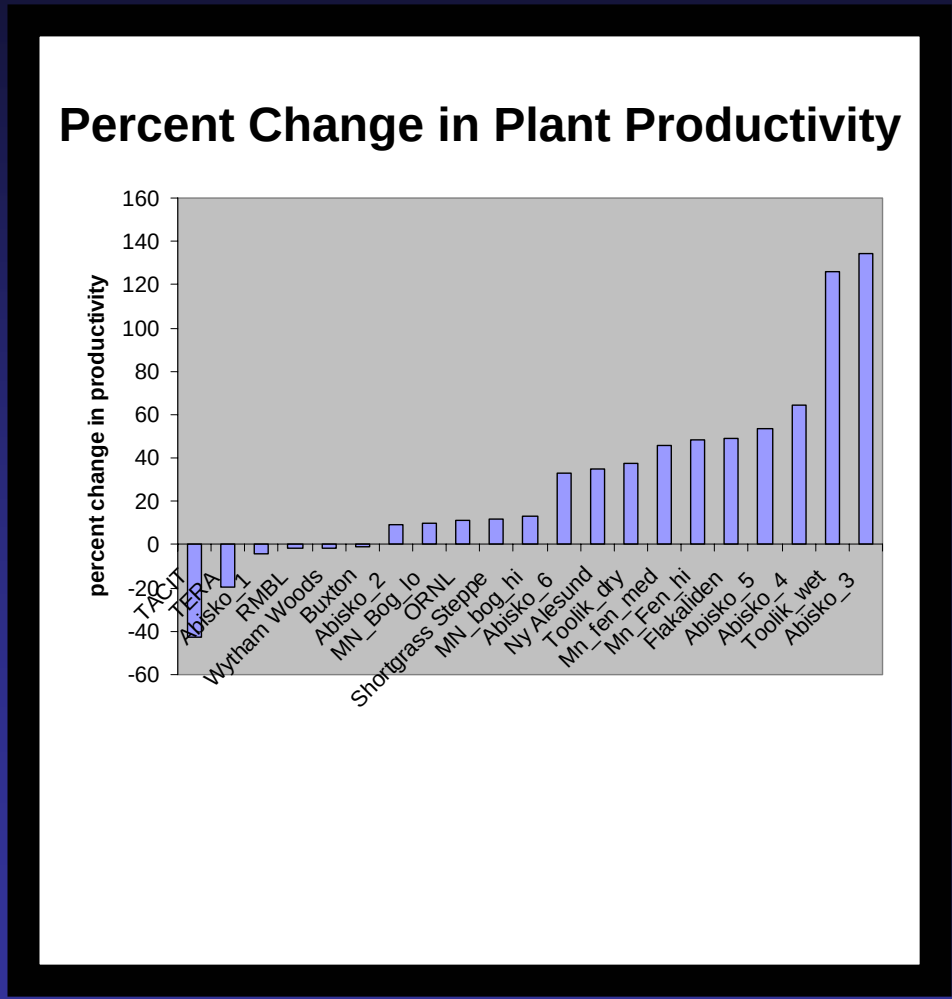
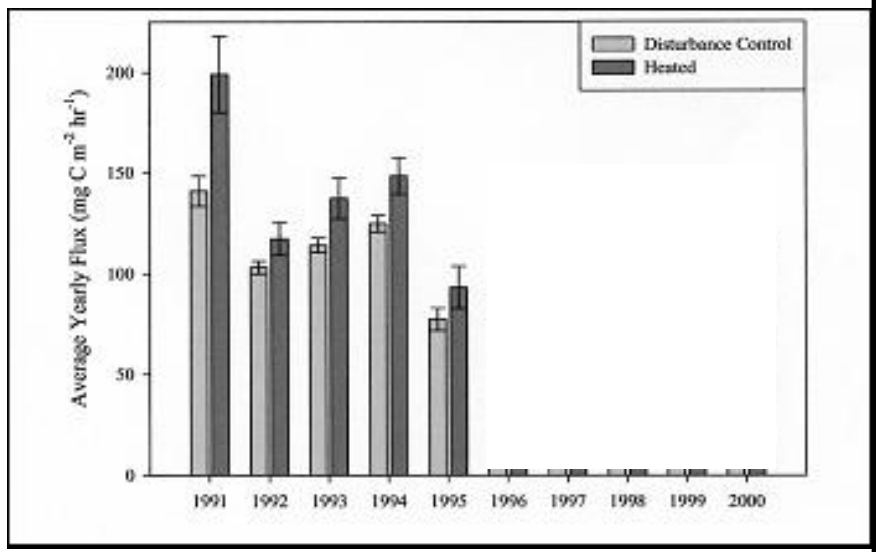


Experimental Manipulations

- **Temperature**

Soil Respiration at the Harvard Forest



Experimental Manipulations

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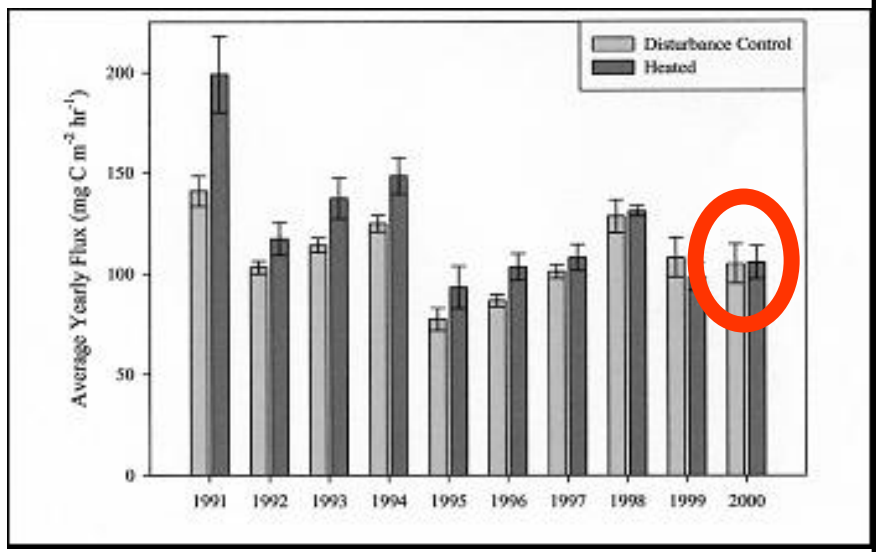


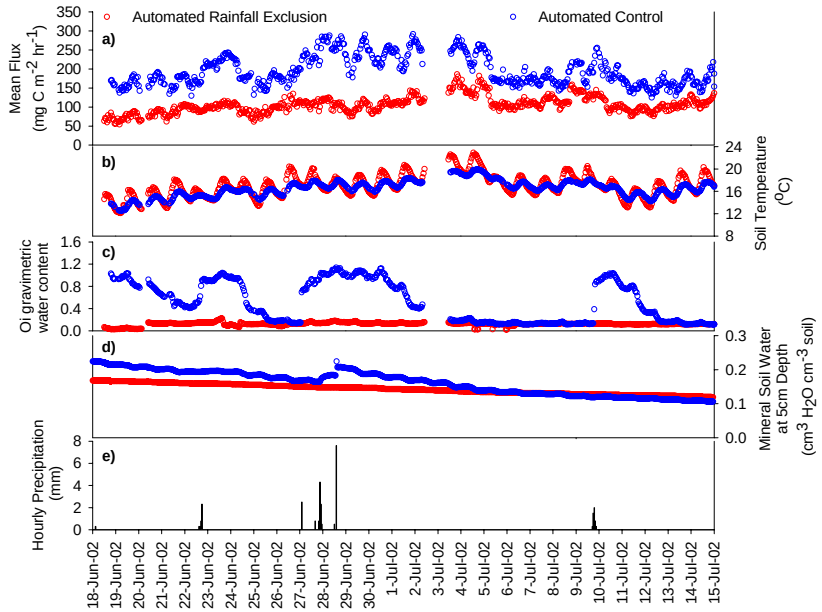
Experimental Manipulations

- **Temperature**
- **Moisture**

Experimental Manipulations

- **Temperature**
- **Moisture**

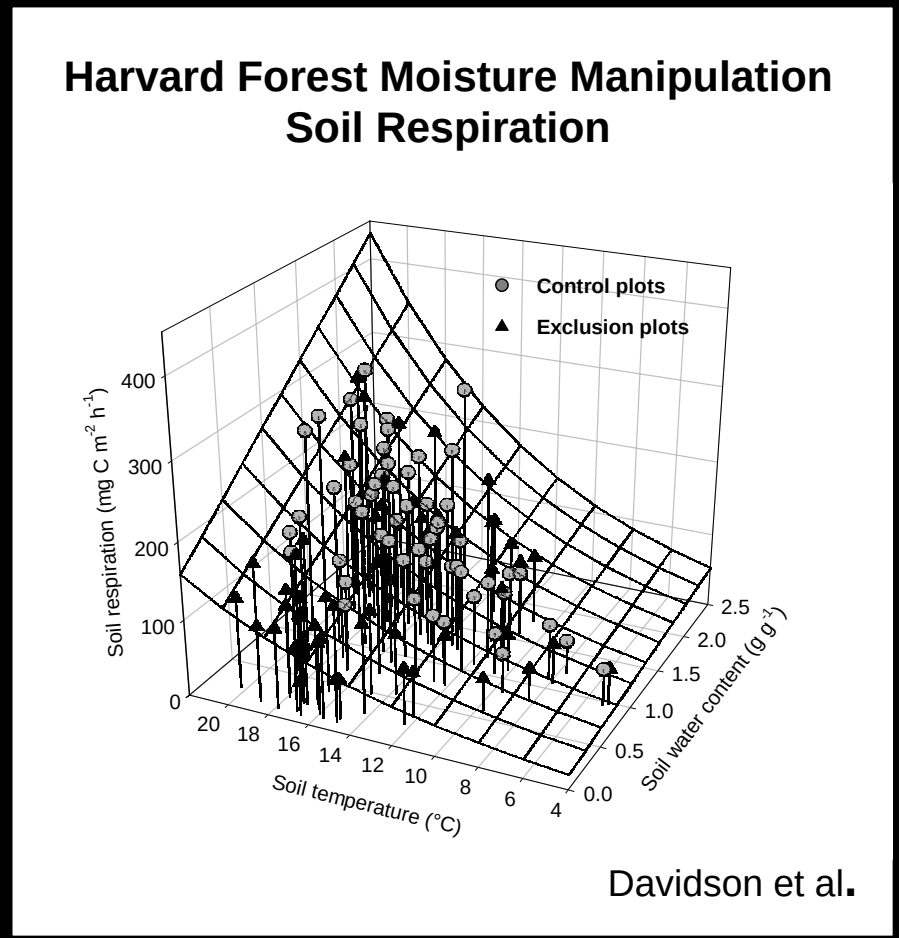
Harvard Forest Moisture Manipulation



Davidson et al.

Experimental Manipulations

- **Temperature**
- **Moisture**



Experimental Manipulations

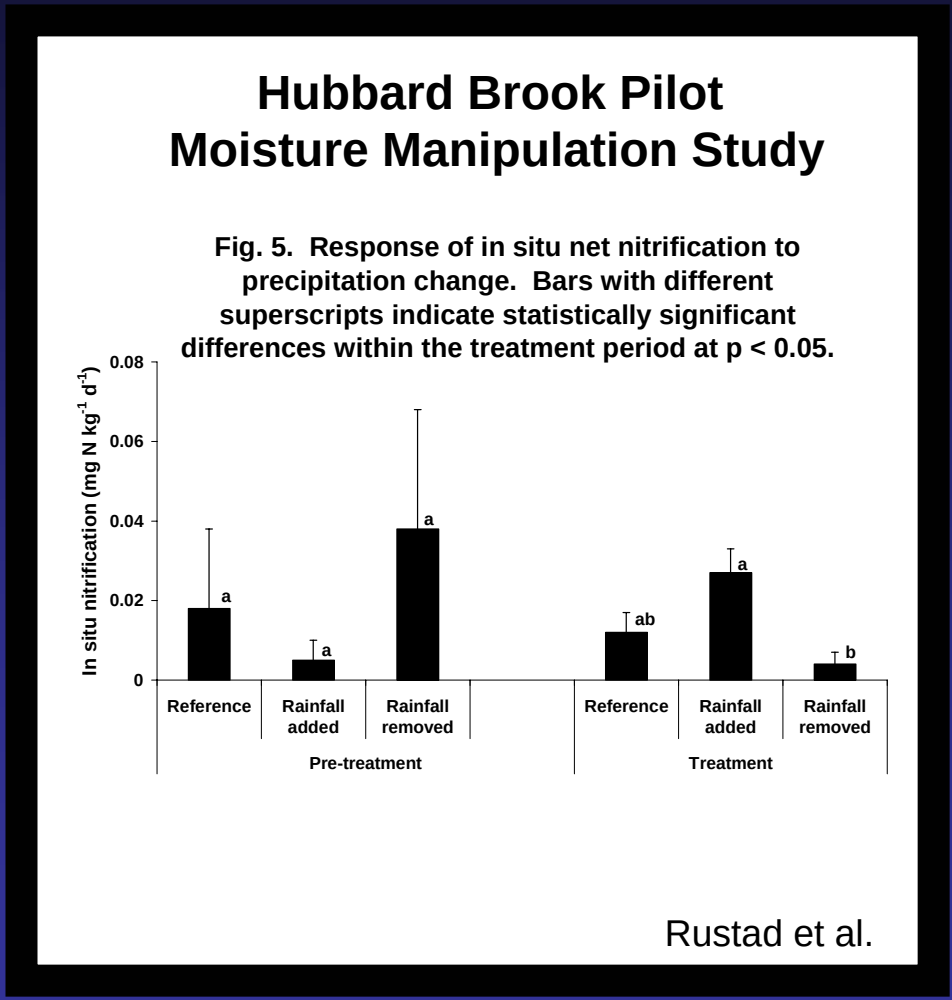
- **Temperature**
- **Moisture**

Hubbard Brook Pilot
Moisture Manipulation Study

Rustad et al.

Experimental Manipulations

- **Temperature**
- **Moisture**



Experimental Manipulations

- **Temperature**
- **Moisture**

Future Research?

$$$$$$$$

Experimental Manipulations

- **Temperature**
- **Moisture**
- **Snow**

Snow Manipulation Experiments in Northeastern North America

Experimental Manipulations

- **Temperature**
- **Moisture**
- **Snow**

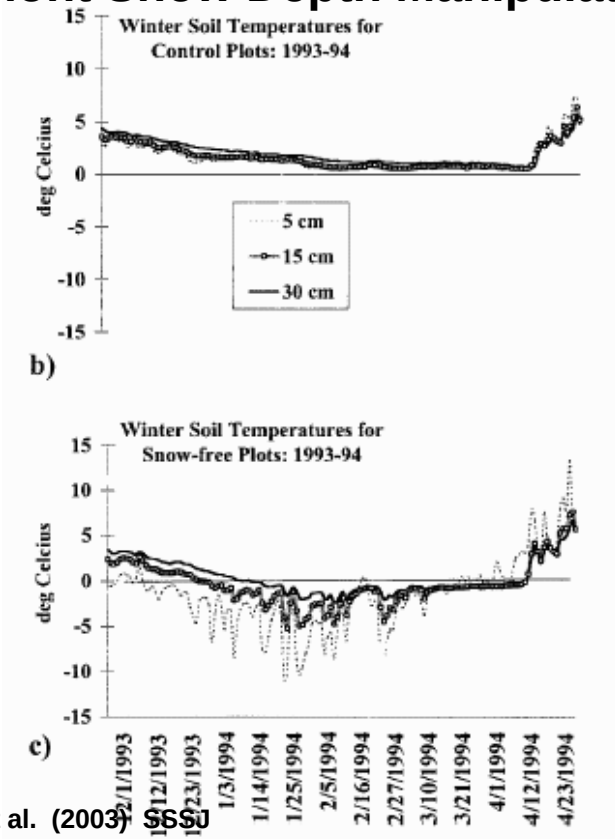
Snow Depth Experiments at:

1. **Underhill,, VT**
2. **Duchesney Experimental Forest, Quebec**
3. **Hubbard Brook, NH**
4. **Harvard Forest, MA**

Experimental Manipulations

- **Temperature**
- **Moisture**
- **Snow**

Vermont Snow Depth Manipulation

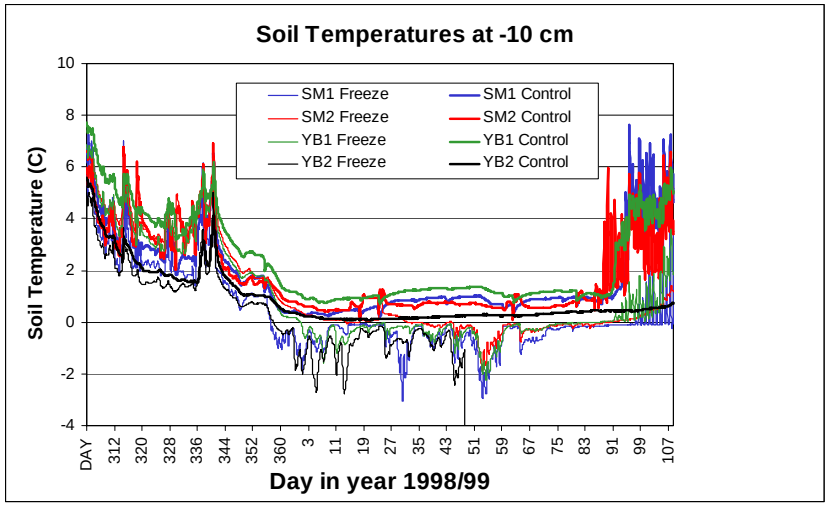


Decker et al. (2003) SSSJ

Experimental Manipulations

- **Temperature**
- **Moisture**
- **Snow**

HBEF Snow Depth Manipulation

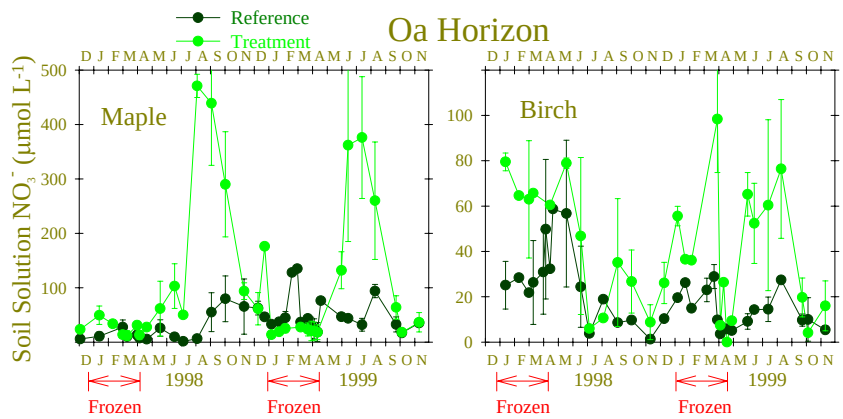


Groffman et al. 2001 Biogeochemistry

Experimental Manipulations

- **Temperature**
- **Moisture**
- **Snow**

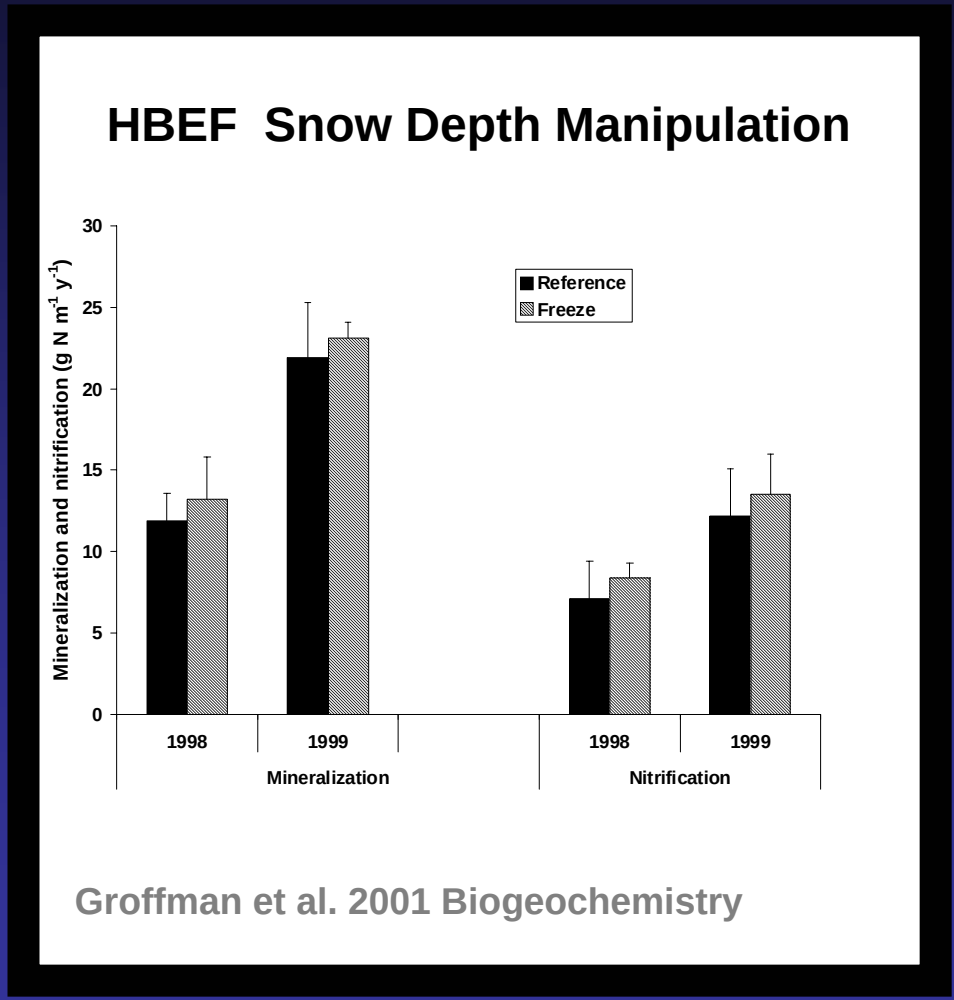
HBEF Snow Depth Manipulation



Groffman et al. 2001 Biogeochemistry

Experimental Manipulations

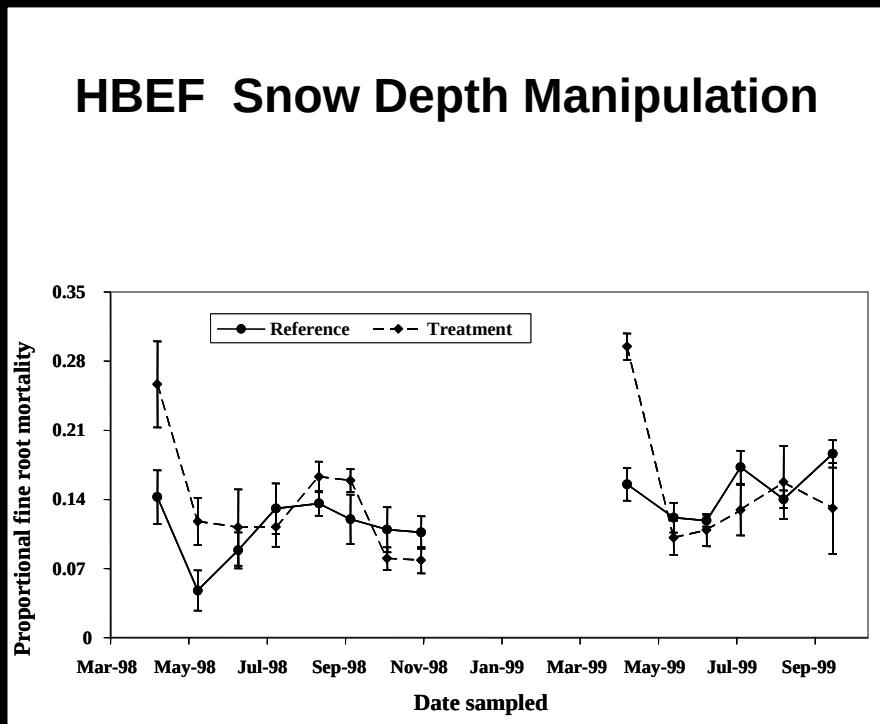
- Temperature
- Moisture
- Snow



Groffman et al. 2001 Biogeochemistry

Experimental Manipulations

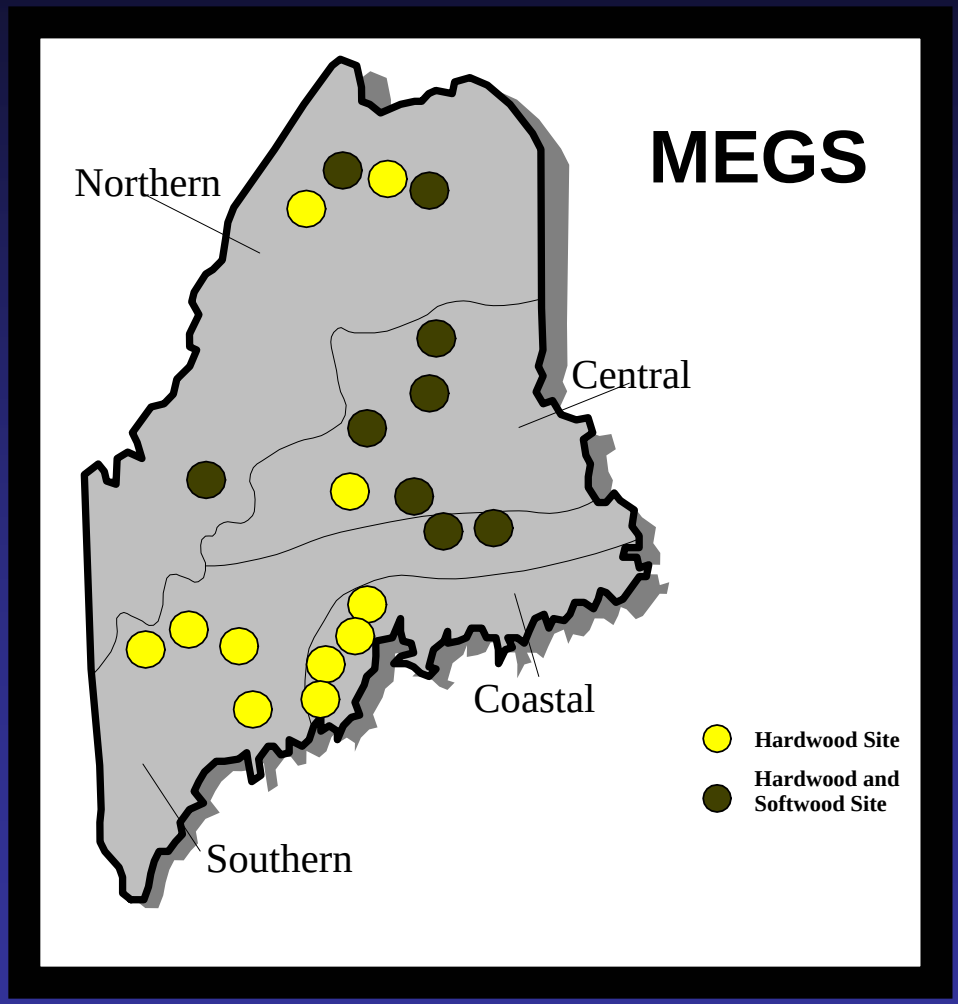
- **Temperature**
- **Moisture**
- **Snow**



Tierney et al. 2001 Biogeochemistry

Gradient Studies

Gradient Studies



- **Maine Environmental Gradient Study – Fernandez et al.**

Gradient Studies

Table 1
Means and ranges for characteristics of the sites in this study.

	Mean	Range
Latitude		44°03' - 46°48'
Longitude		68°06' - 70°35'
Elevation (m)	234	46 - 883
Slope (%)	5	1 - 11
Forest Floor Thickness (cm)	7	2 - 14
Basal Area (m^2 ha^{-1})	29	17 - 40
Conifer (% Basal Area)	38	[illegible]
Mean Annual Air Temperature (C°)	4.5	2.0 - 6.2
Mean Annual Soil Temperature (C°)	6.5	5.2 - 7.3
Mean May-Oct Air Temperature (C°)	13.5	11.4 - 14.7
Mean May-Oct Soil Temperature (C°)	12.3	10.3 - 13.4
Frost-Free Days	213	113 - 259
Growing Degree Days	2326	[illegible]
Precipitation (cm)	103	90 - 140

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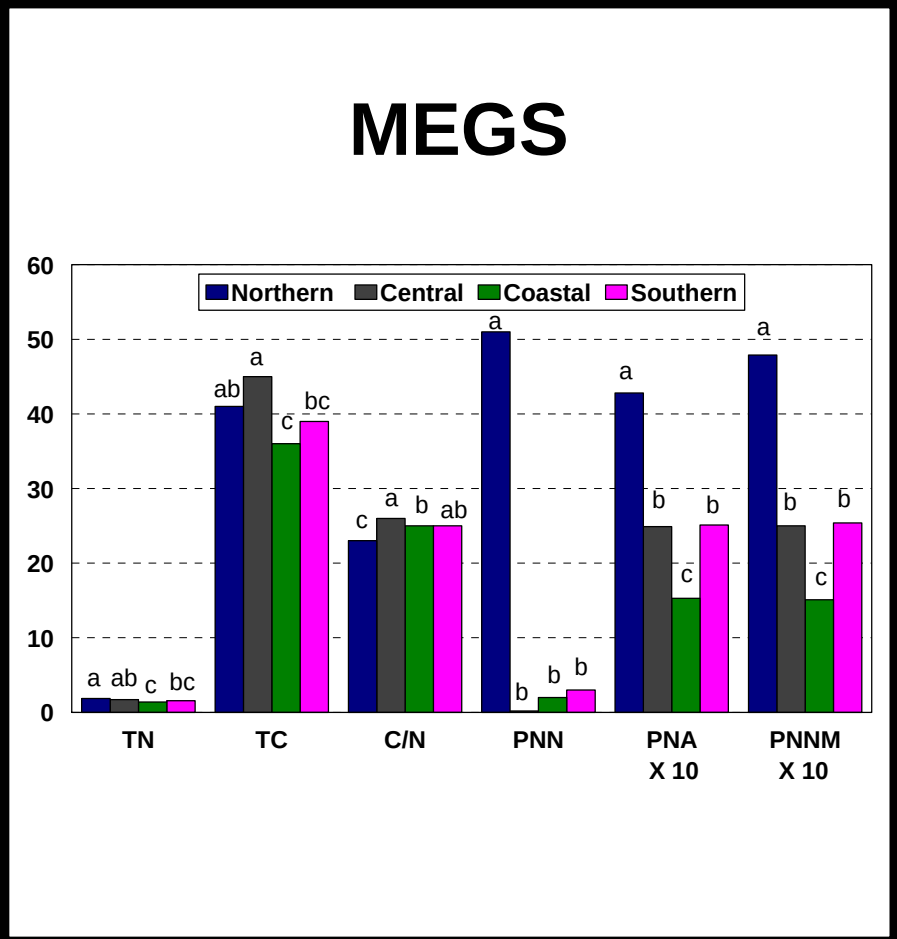
Gradient Studies



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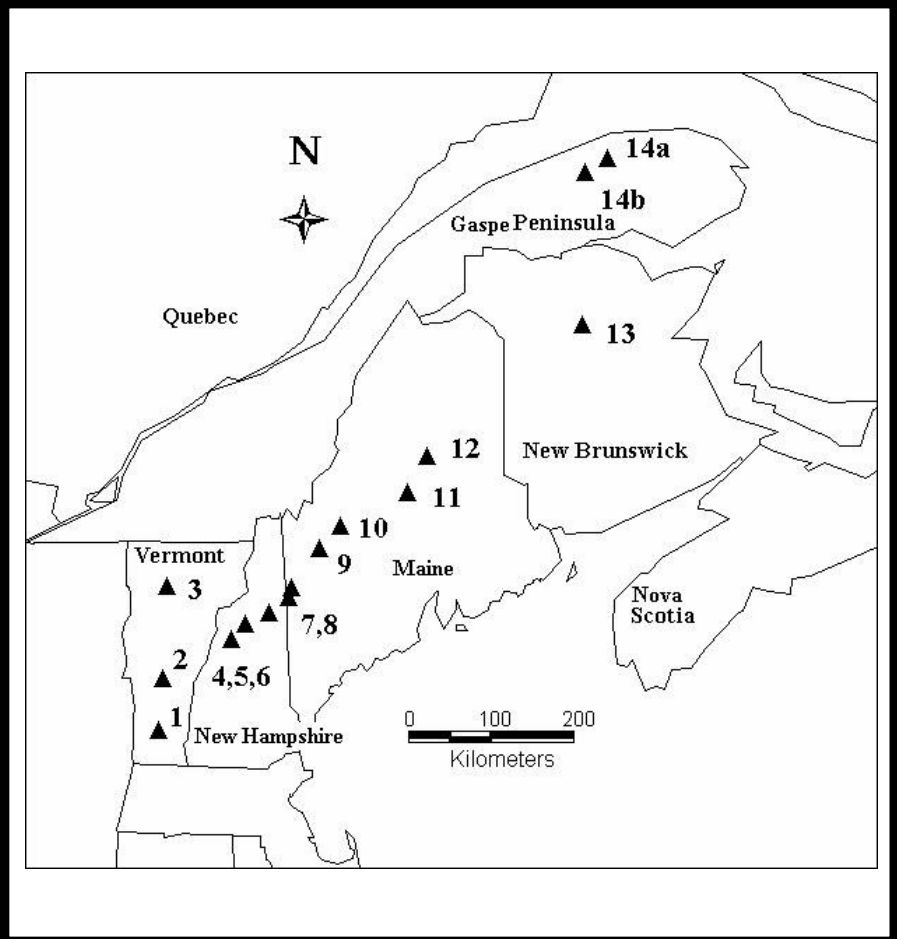
Gradient Studies



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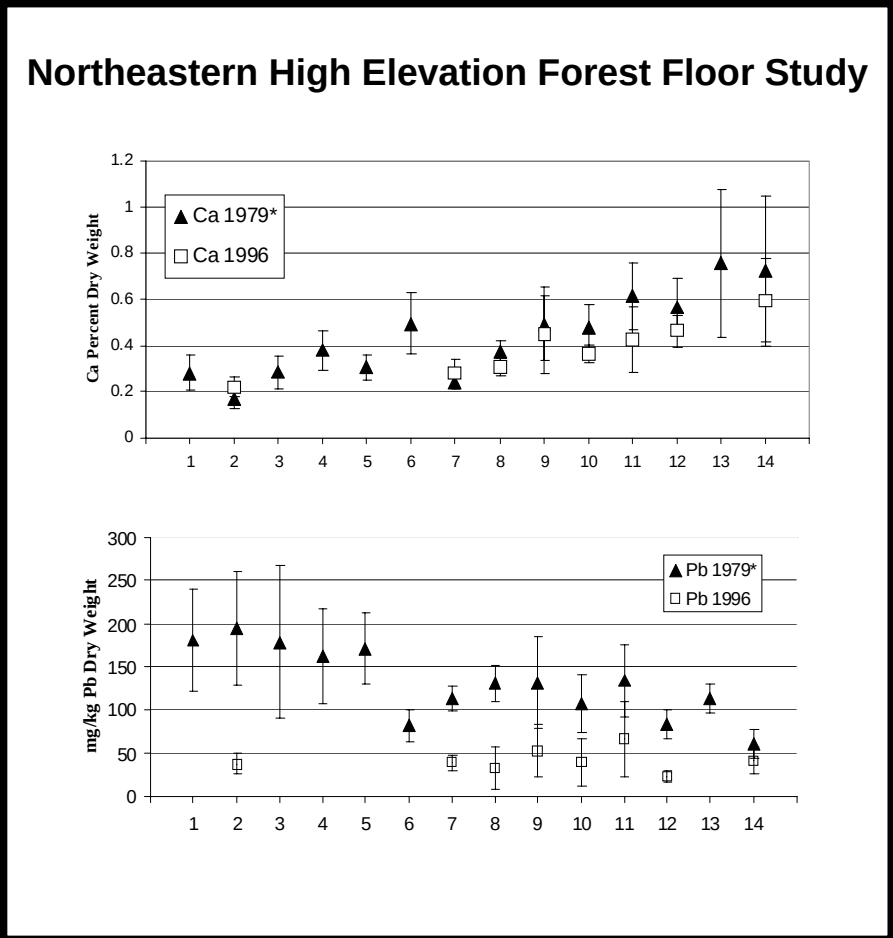
- **Northeastern High Elevation Forest Floor Study - Hanson et al.; Evans et al.**

Gradient Studies



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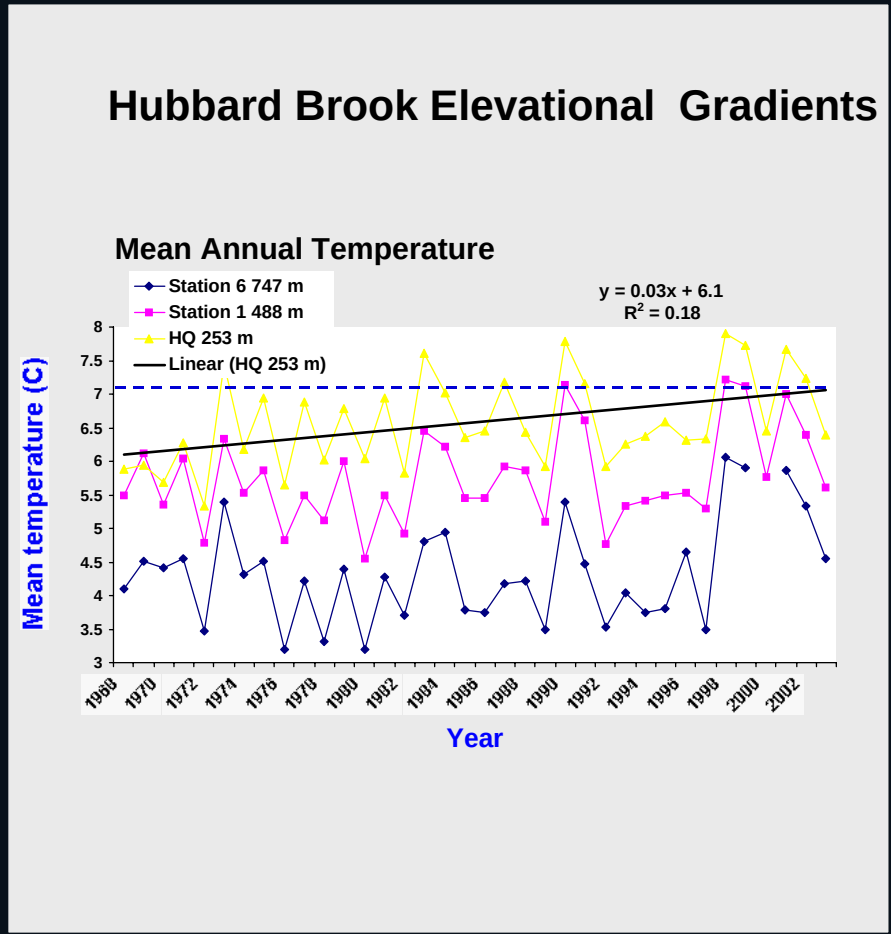
Gradient Studies



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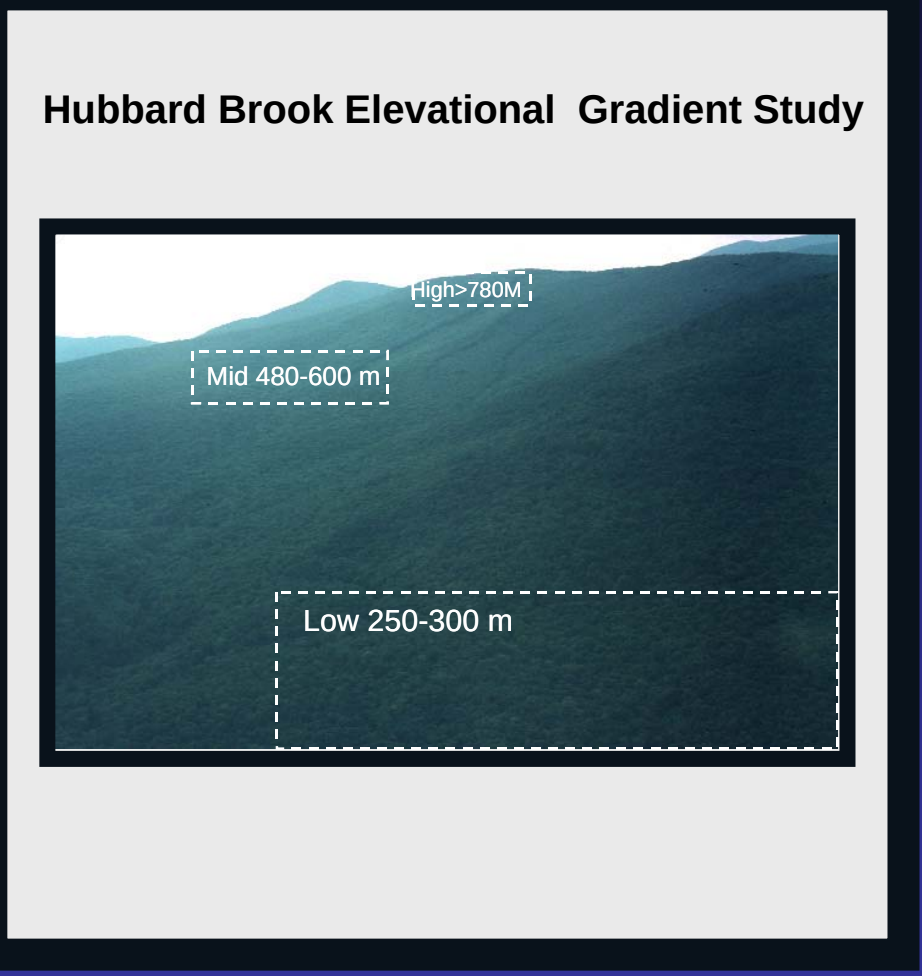
- Northeastern High Elevation Forest Floor Study - Hanson et al.; Evans et al.
- Hubbard Brook Environmental Gradient Study – Groffman et al.

Gradient Studies



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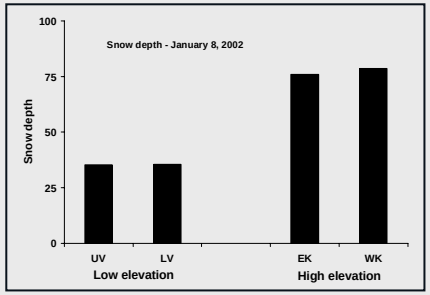
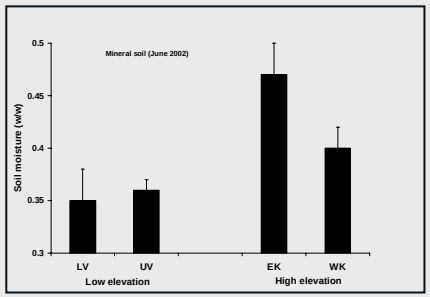
Gradient Studies

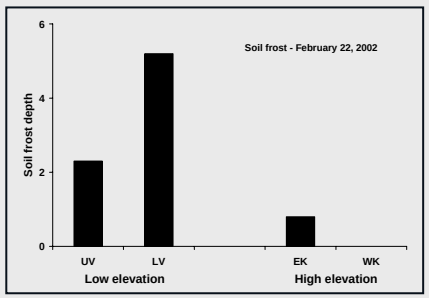
More snow at higher elevation



Higher soil moisture at higher elevation



Less soil freezing at higher elevation



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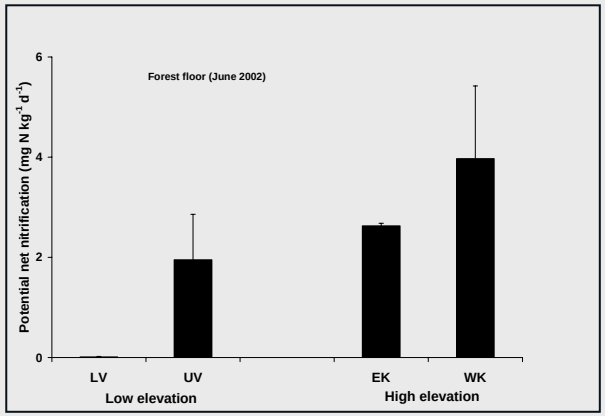
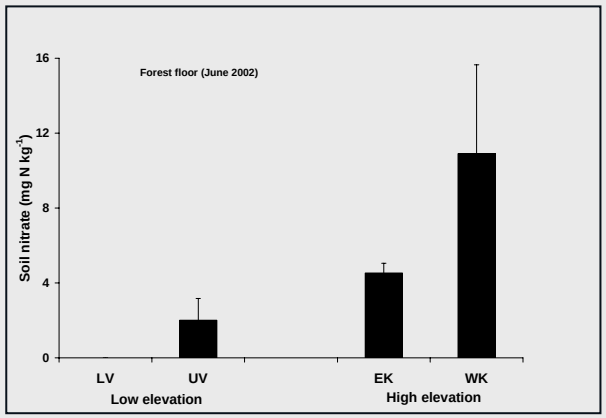
Gradient Studies

Higher soil nitrification at higher elevation



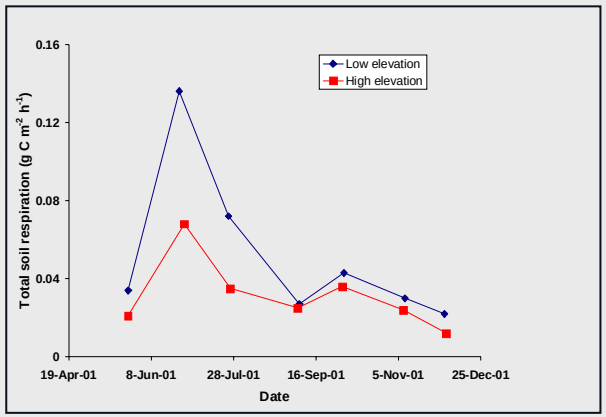
Higher soil NO_3^- at higher elevation



- Maine Environmental Gradient Study – Fernandez et al.
- Northeastern High Elevation Forest Floor Study - Hanson et al.; Evans et al.
- Hubbard Brook Environmental Gradient Study – Groffman et al.

Gradient Studies

Higher soil respiration at lower elevation



- **Maine Environmental Gradient Study – Fernandez et al.**
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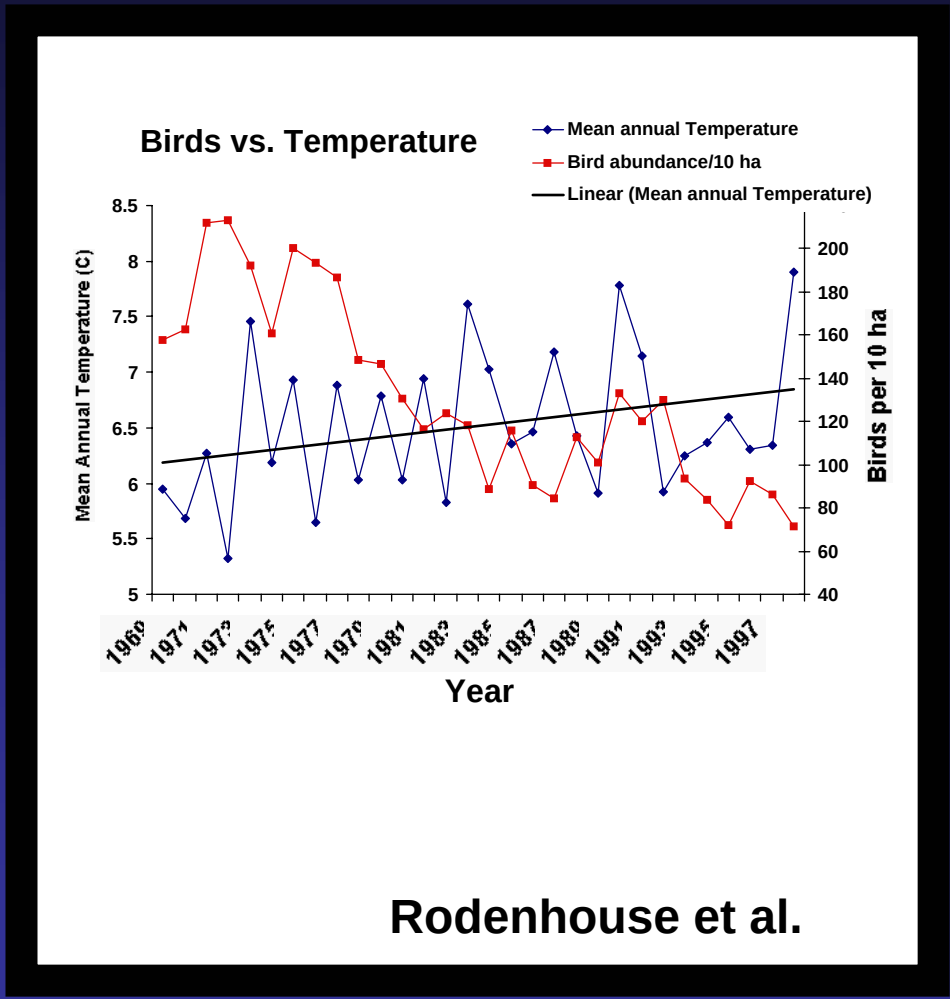
Biological Observations

Biological Observations

- **Birds and small mammals**

Biological Observations

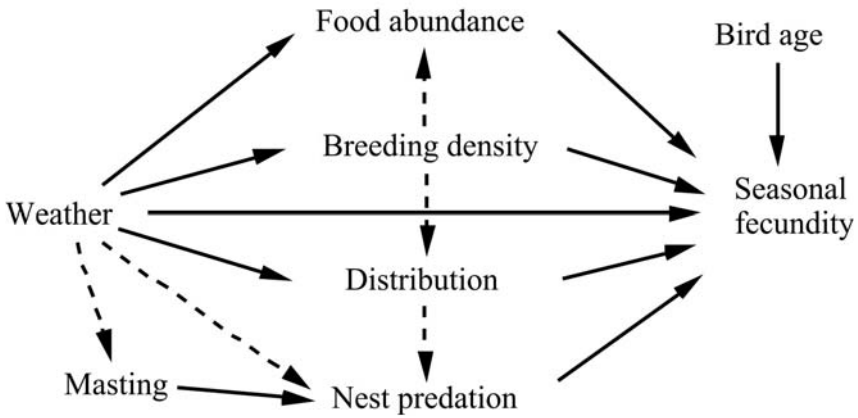
- **Birds and small mammals**



Biological Observations

- **Birds and small mammals**

How might climate change affect bird populations?

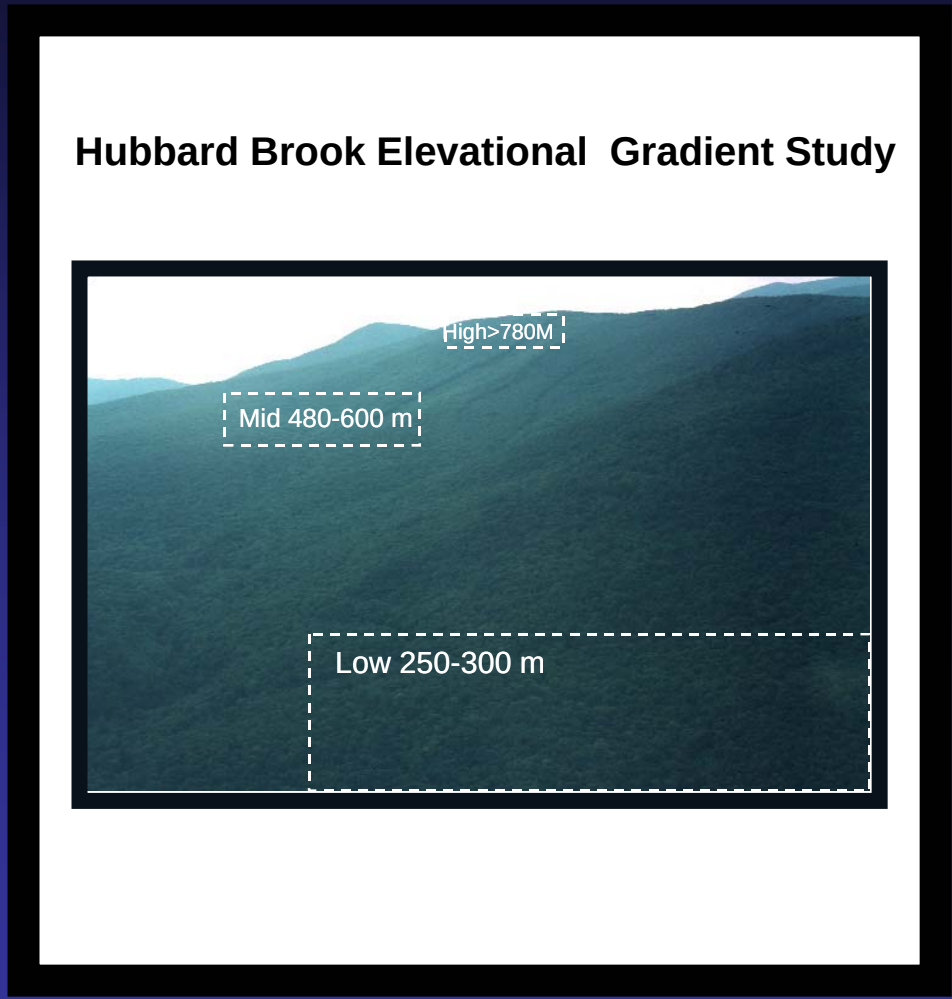


Directly and indirectly

Rodenhouse et al.

Biological Observations

- **Birds and small mammals**



Biological Observations

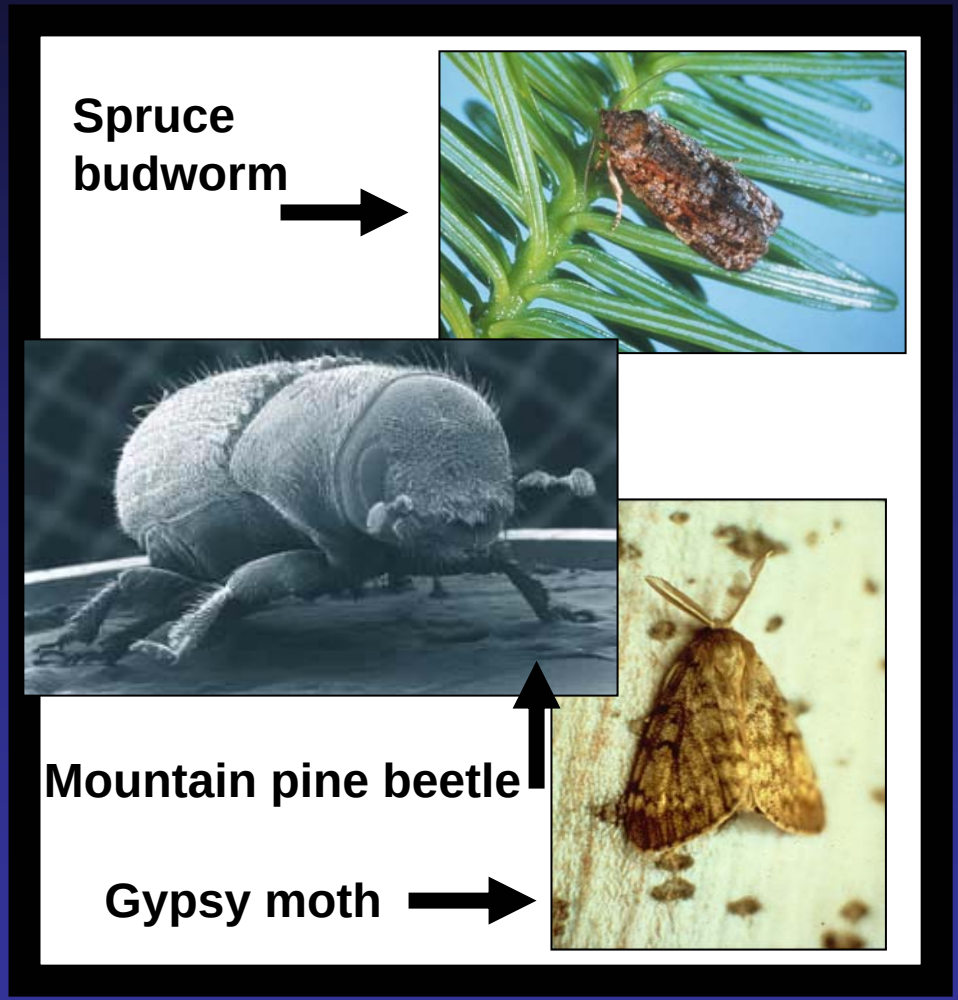
- **Birds and small mammals**

Climate and Song Bird Populations

- Food is more abundant during warm, dry years.
- Distribution of birds will shift towards lower elevations in years with cold spring weather.
- Bird densities will be higher in years where weather conditions lead to synchronous arrival of spring migrants.
- Rate of nest predation:
  - will increase in summers following a mast seed crop in the preceding summer/autumn.
  - will decline when inclement weather depresses nest predator activity.

Biological Observations

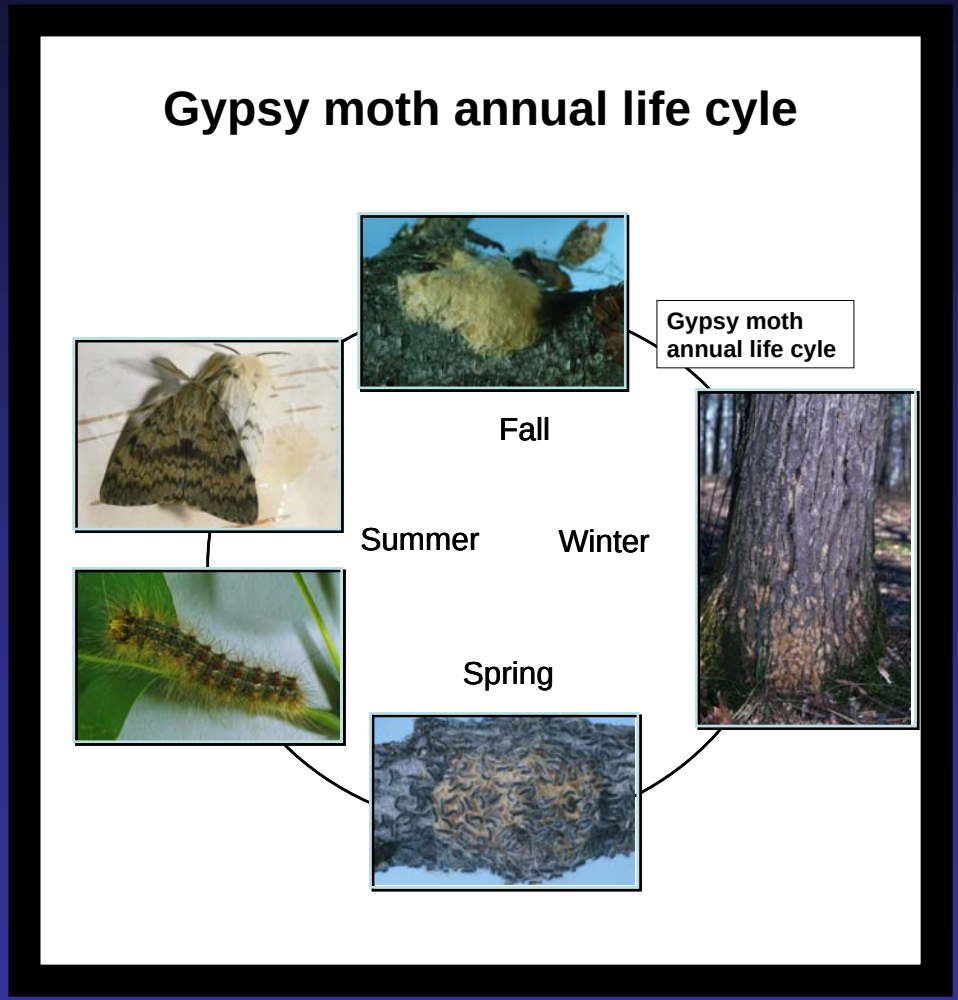
- **Birds and small mammals**
- **Forest Insects**



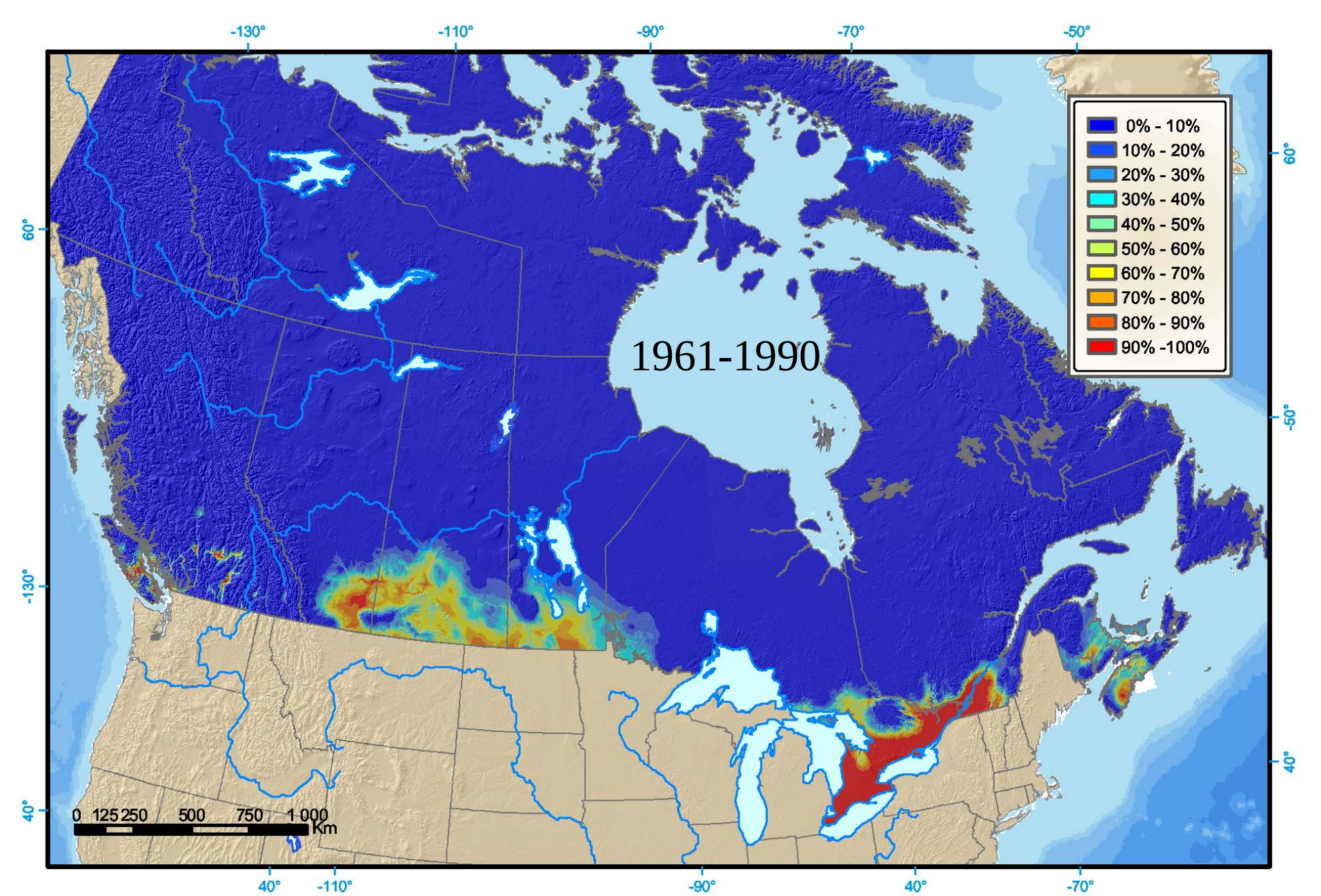
Barry Cook et al.

Biological Observations

- **Birds and small mammals**
- **Forest Insects**



Barry Cook et al.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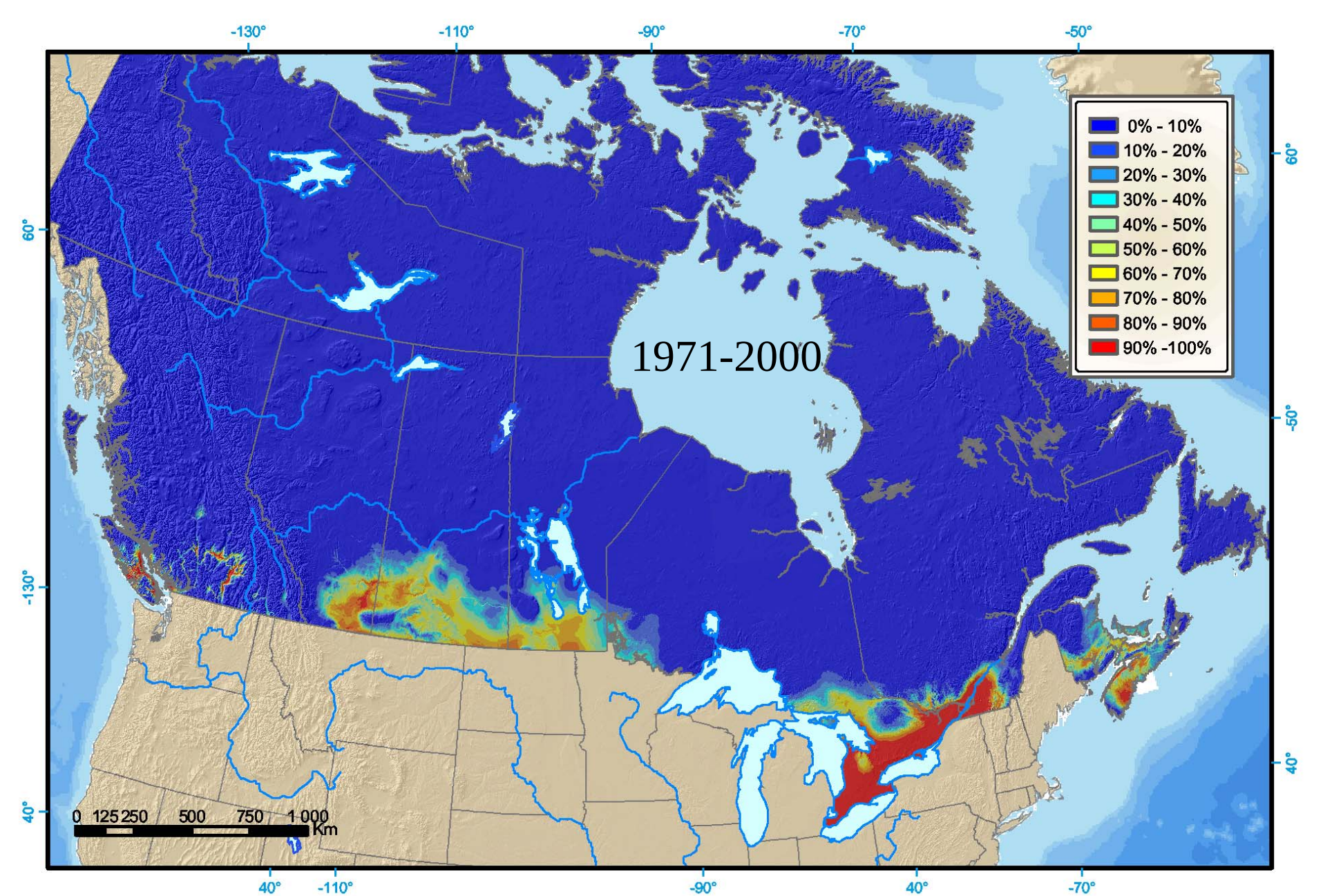
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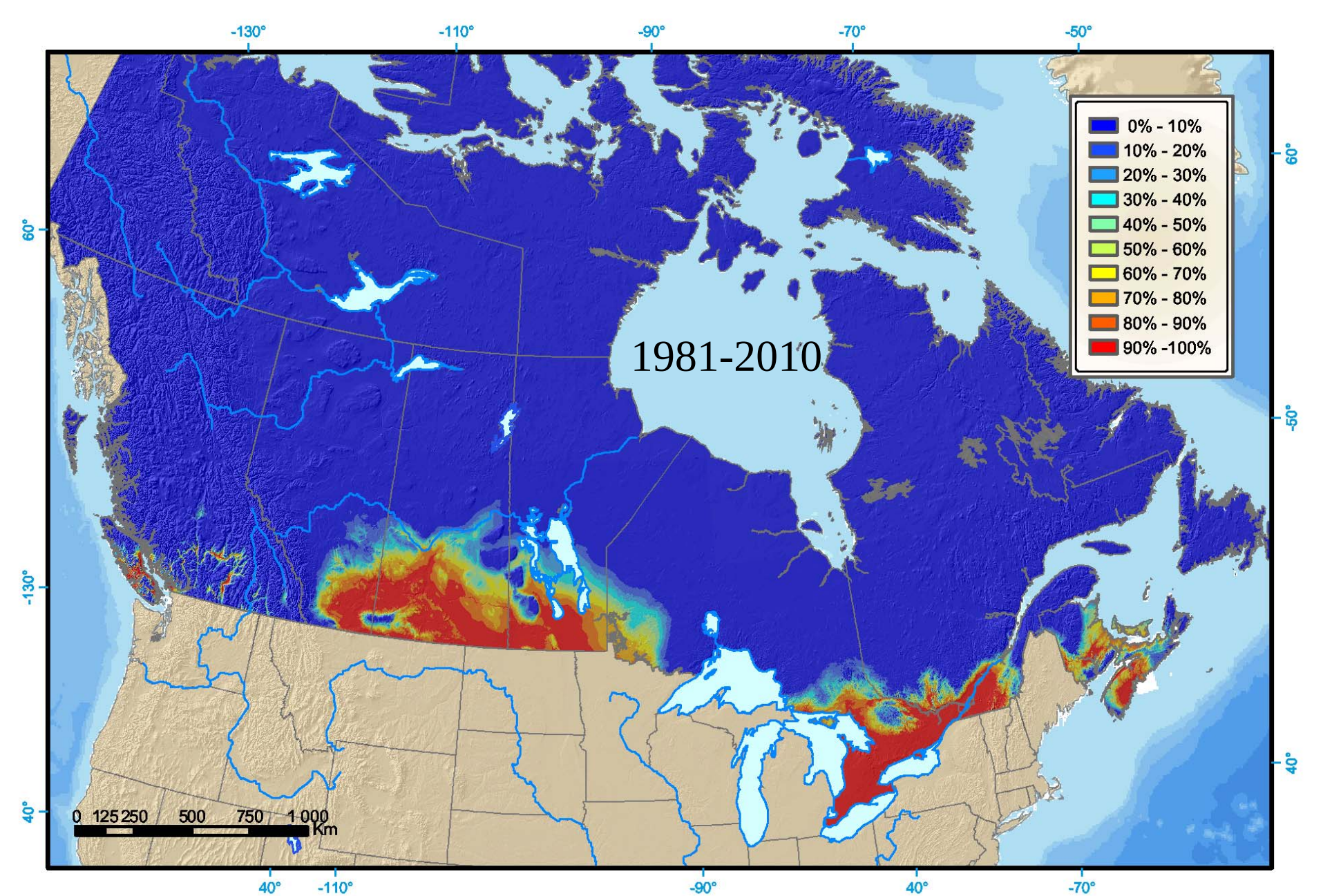
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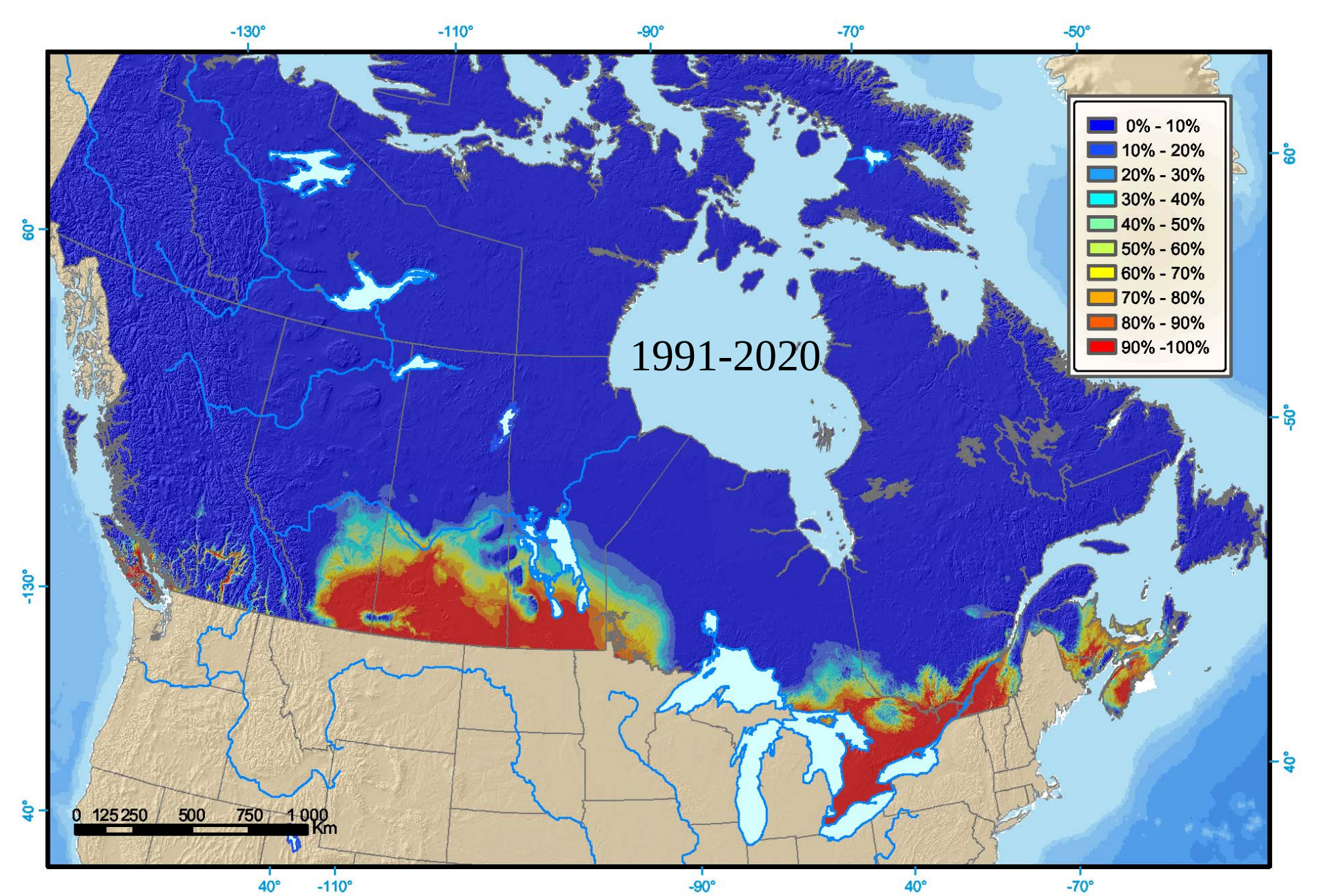
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1991-2020
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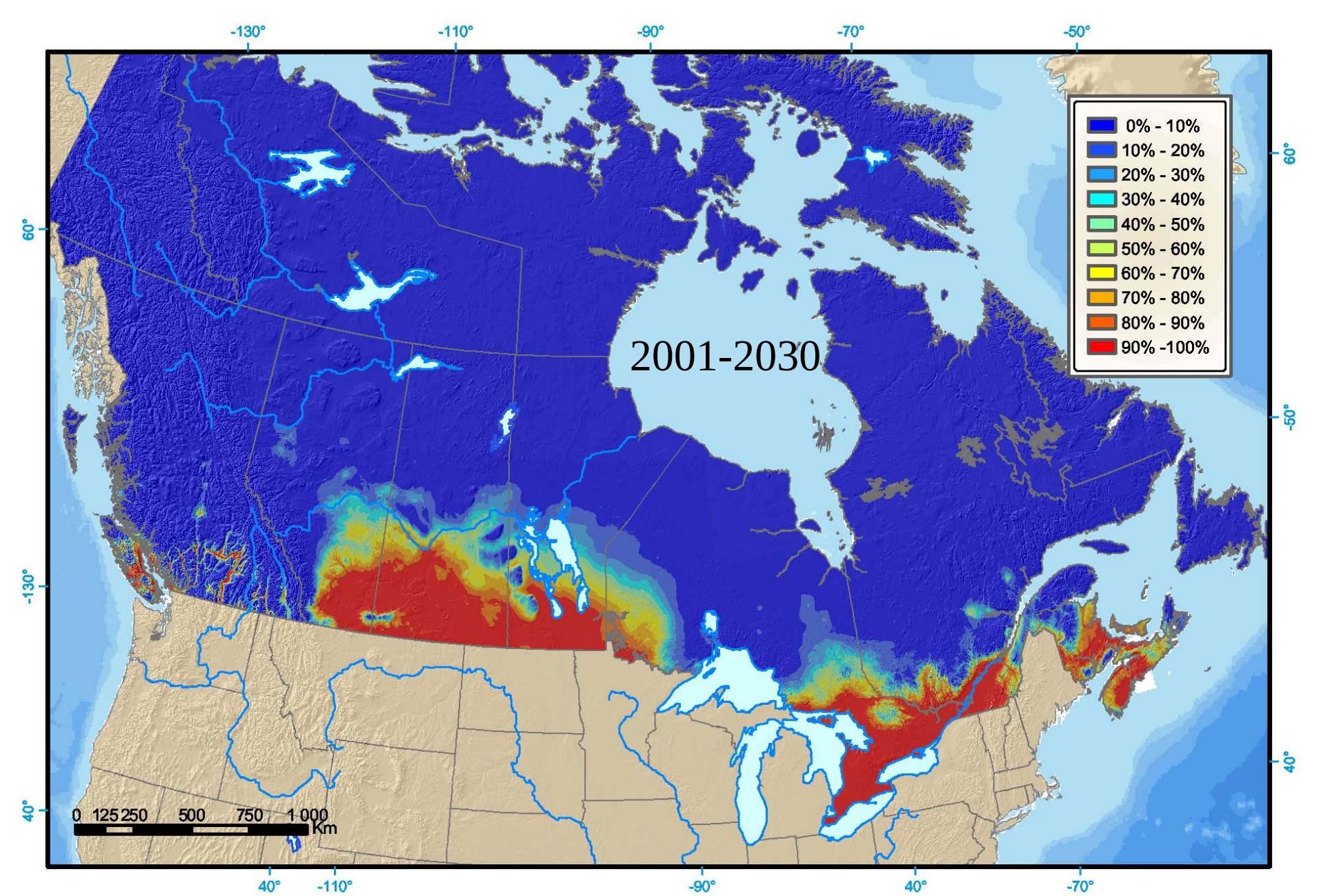
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2001-2030
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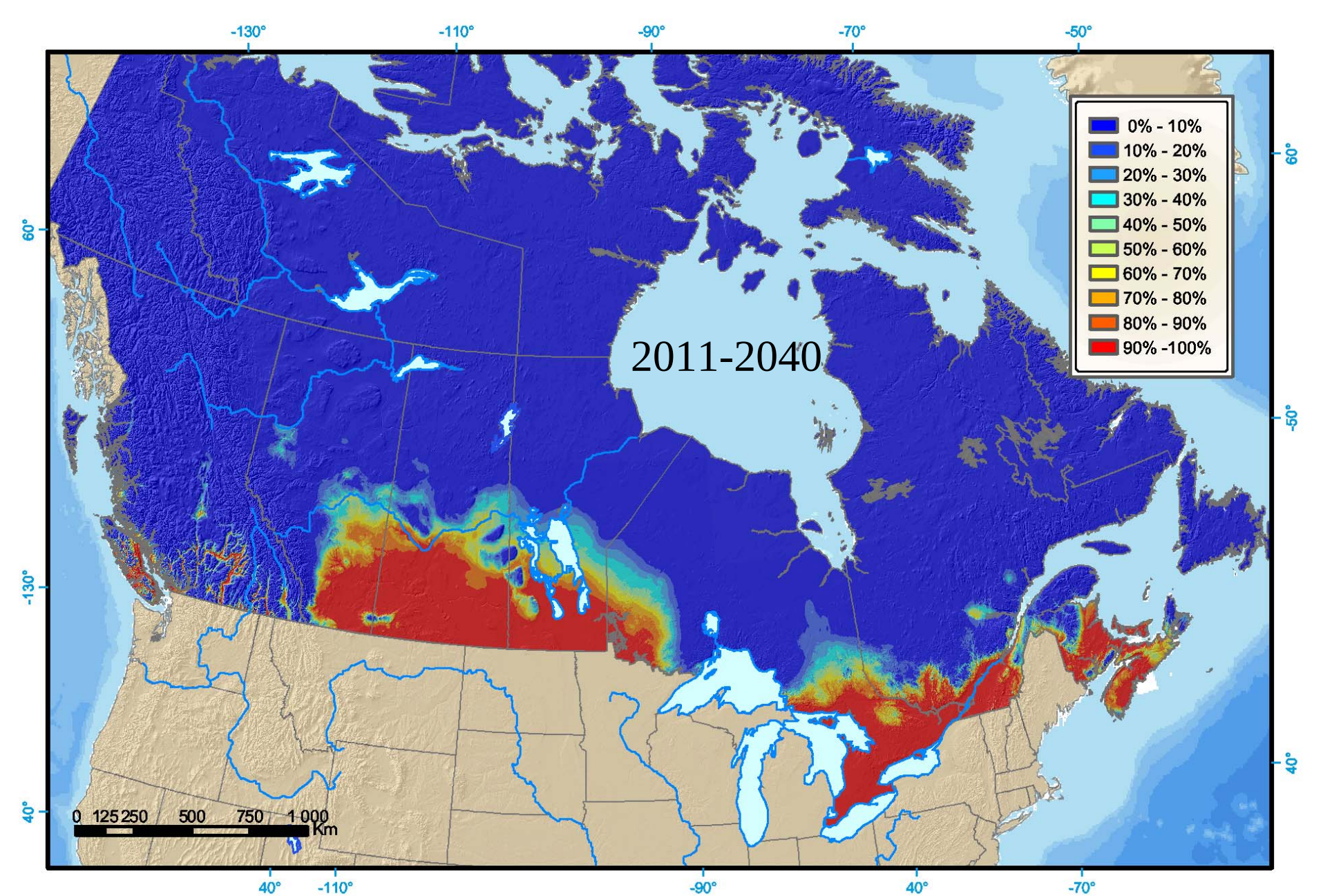
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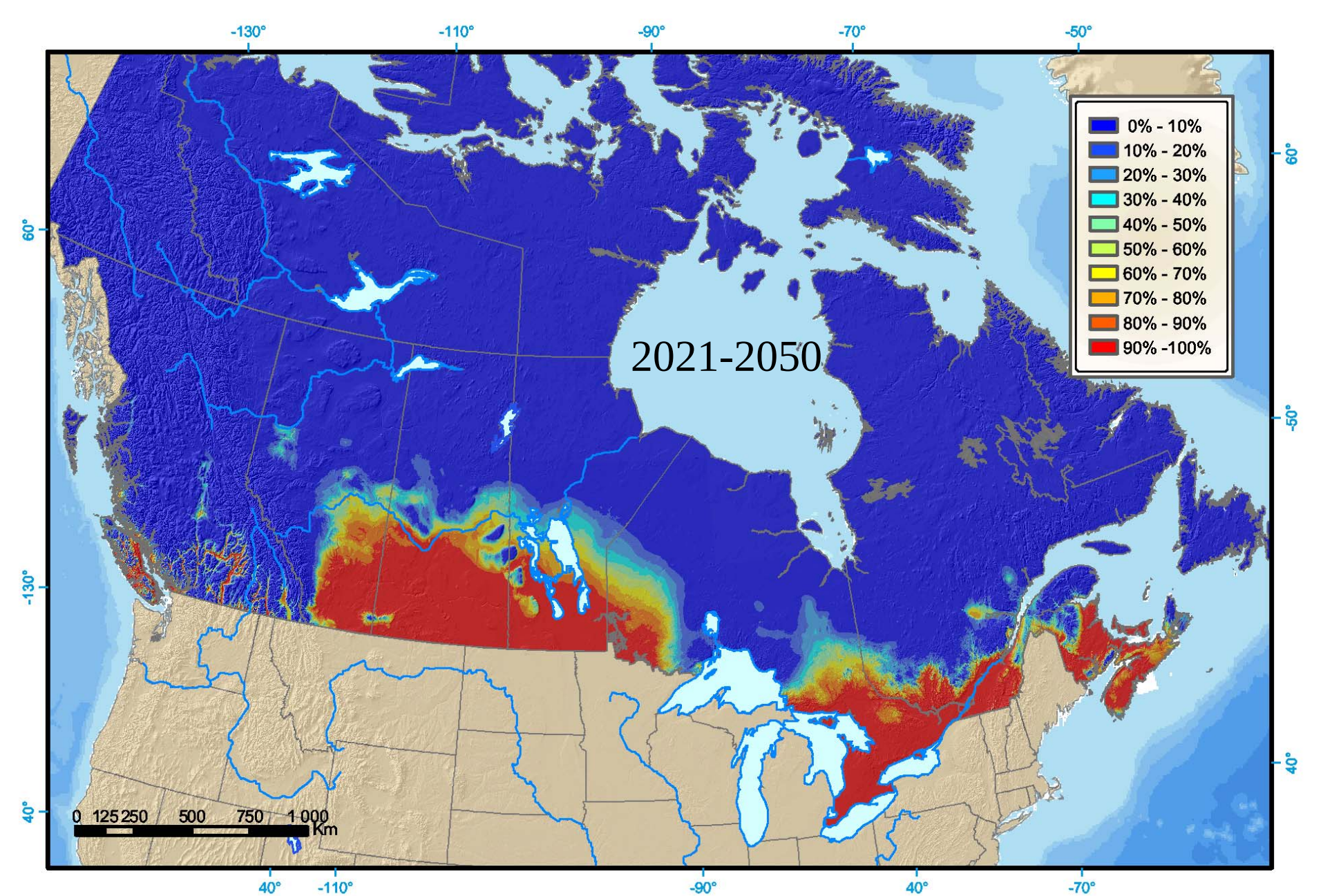
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2021-2050
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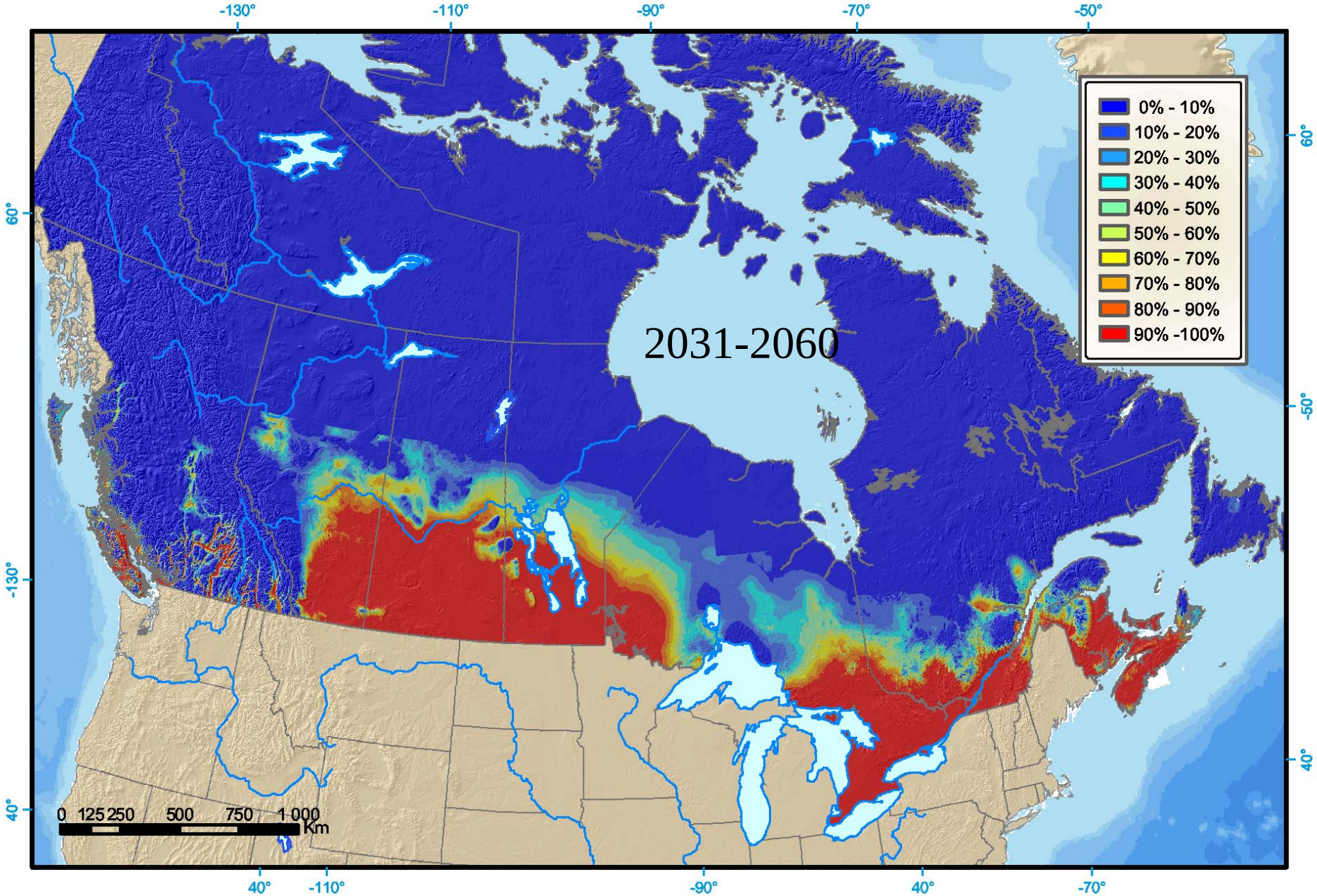
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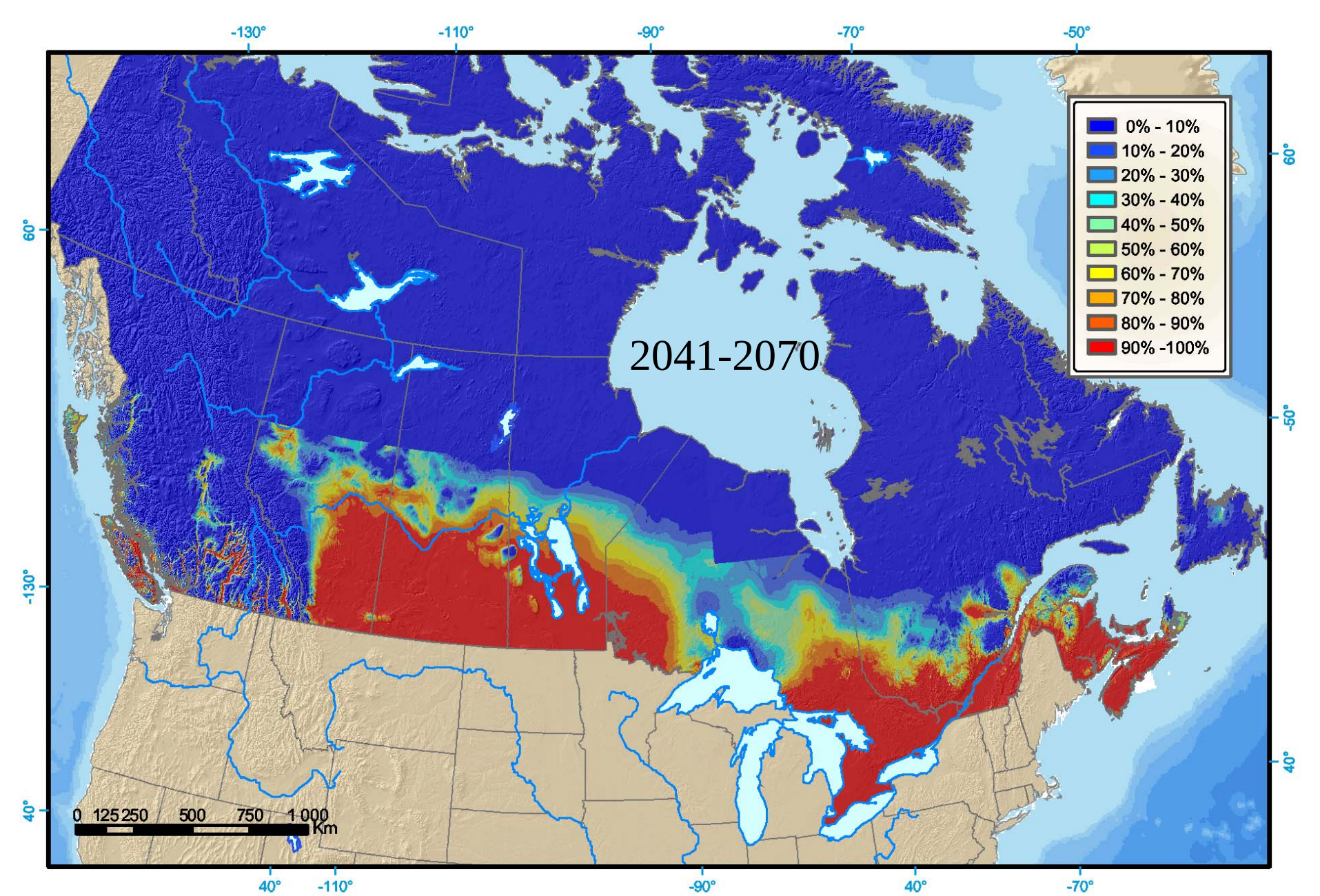
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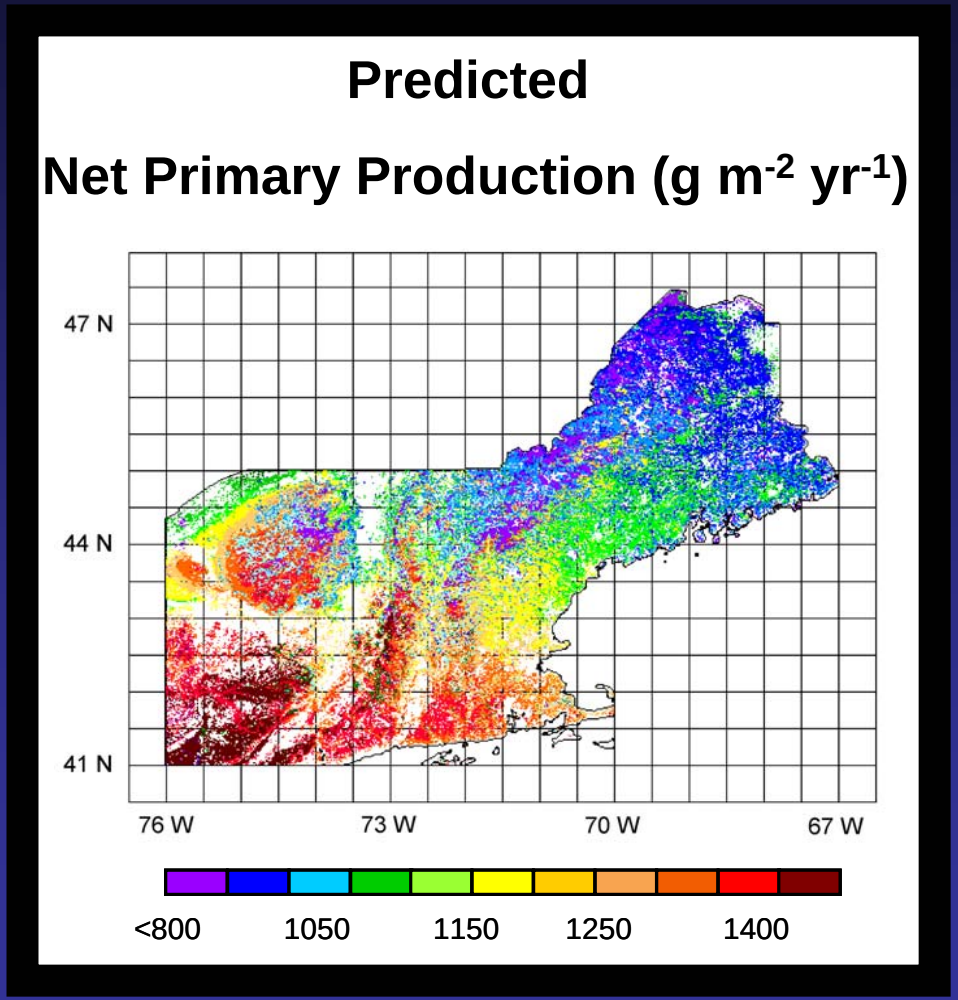
Modeling

Modeling

- **PnET**



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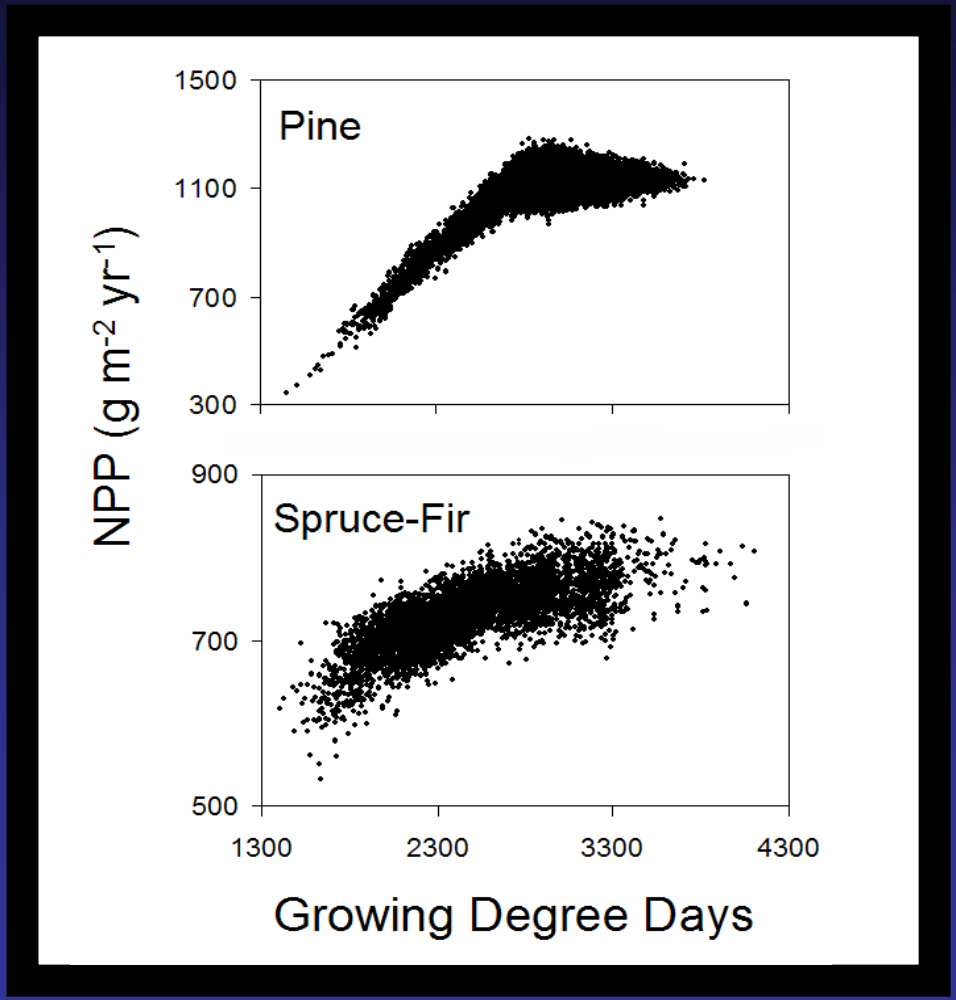
Modeling

- **PnET**



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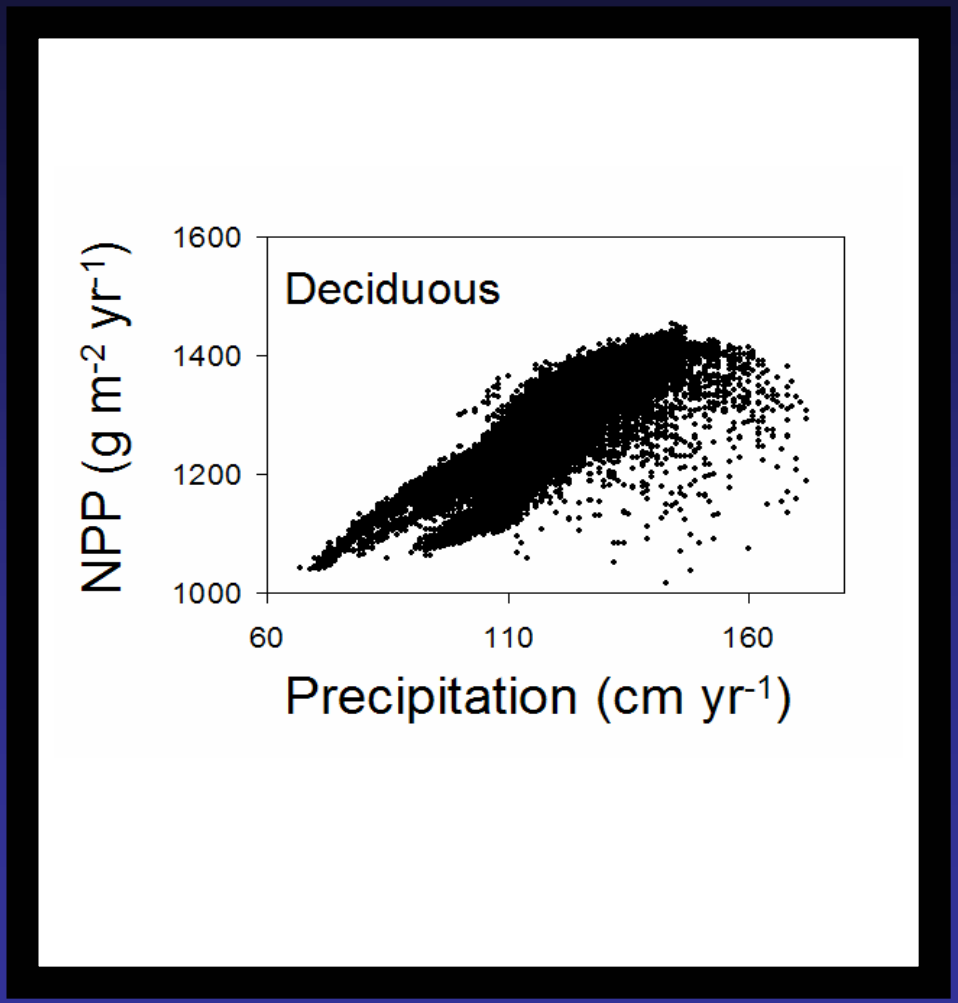
Modeling

- **PnET**



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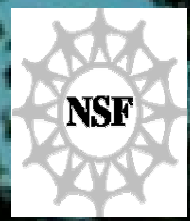
A New Program on:
Synthesis of Climate Change Research in Northeastern US and Eastern Canadian Forest Ecosystems

NERC CVC Working Group

Funded by NSRC and NSF RCN



Why Northern Forest Ecosystems?

- **The dominant land cover type across much of the Northeastern United States and Eastern Canada**
- **Provide important ecosystem services, including:**
  - **Forest Products**
  - **Tourism**
  - **Recreation**
  - **Clean air**
  - **Clean water**
  - **Biodiversity**

Goals

- Increase communication amongst global change scientists in the northeastern U.S. and eastern Canada
- Synthesize the accumulating research on the response of northern forest ecosystems to climate change
- Make this summary available to policy makers, land and resource managers, stakeholders and the interested public

Approach

- **Phase 1: a scientific synthesis of climate variability and change research in the region**

Climate Variability and Change: Consequences for Northern Forest Ecosystems

1. Introduction
2. Historical Record for Past Climate Change within the Region
3. Indicators of Past Climate Change within the Region (lake and river ice-out, river flow timing, phenology, etc)
4. Updated Climate Projections for the Region
5. Current Regional Scientific Efforts
   a. Long-term Monitoring
   b. Gradients (space-for-time substitutions)
      (i) Elevational
      (ii) Latitudinal
   c. Experimental Manipulations
      (i) Temperature
      (ii) Precipitation
      (iii) Snow
   d. Biological Observations
      (i) Birds
      (ii) Small mammals
      (iii) Insects
      (iv) Invasive species
      (v) Biodiversity Species Redistribution
   e. Modeling
6. Ecological Implications for Northern Forest Ecosystems
   a. Forest impacts
   b. Water impacts
   c. Biogeochemical impacts
   d. Pests and Pathogens
   e. Interactions with O_3, N and S deposition, Hg, and fire
7. Future Scientific Research Needs

Approach

- **Phase 2: the 'translation' of this document for the non-scientific community, as a:**
  - **Forest Service General Technical Report (GTR)**
  - **Fact Sheets**
  - **Web site**

Timeline

2003/2004 → **2005** → **2006** →

	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
First CVC Meeting	X																									
Proposal Planning		X	X	X	X	X																				
Proposal submission							X																			
Proposal Funded								X																		
Initial Planning									X	X	X	X														
Second CVC Meeting													X													
Synthesis Paper Writing													X	X	X	X	X	X	X							
Third CVC Meeting																			X							
Outreach Paper Writing																			X	X	X	X	X	X	X	
Final Products																										X

Final Thought….

It is hoped that these products will be used to provide an unbiased scientific basis for forestry related policy and land management decisions within the region.