Climate as a Driver of Ecological Change

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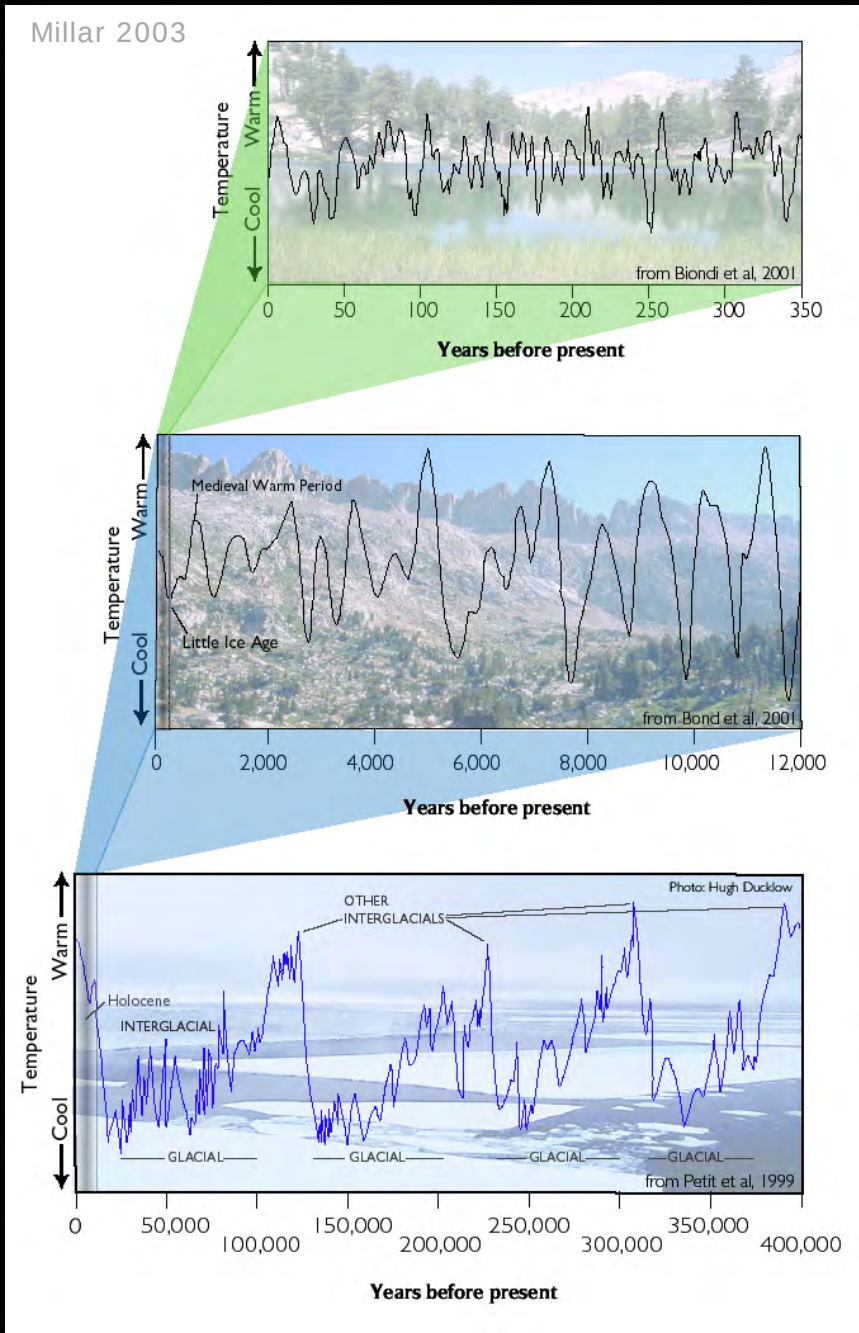
Earth's Climate System:

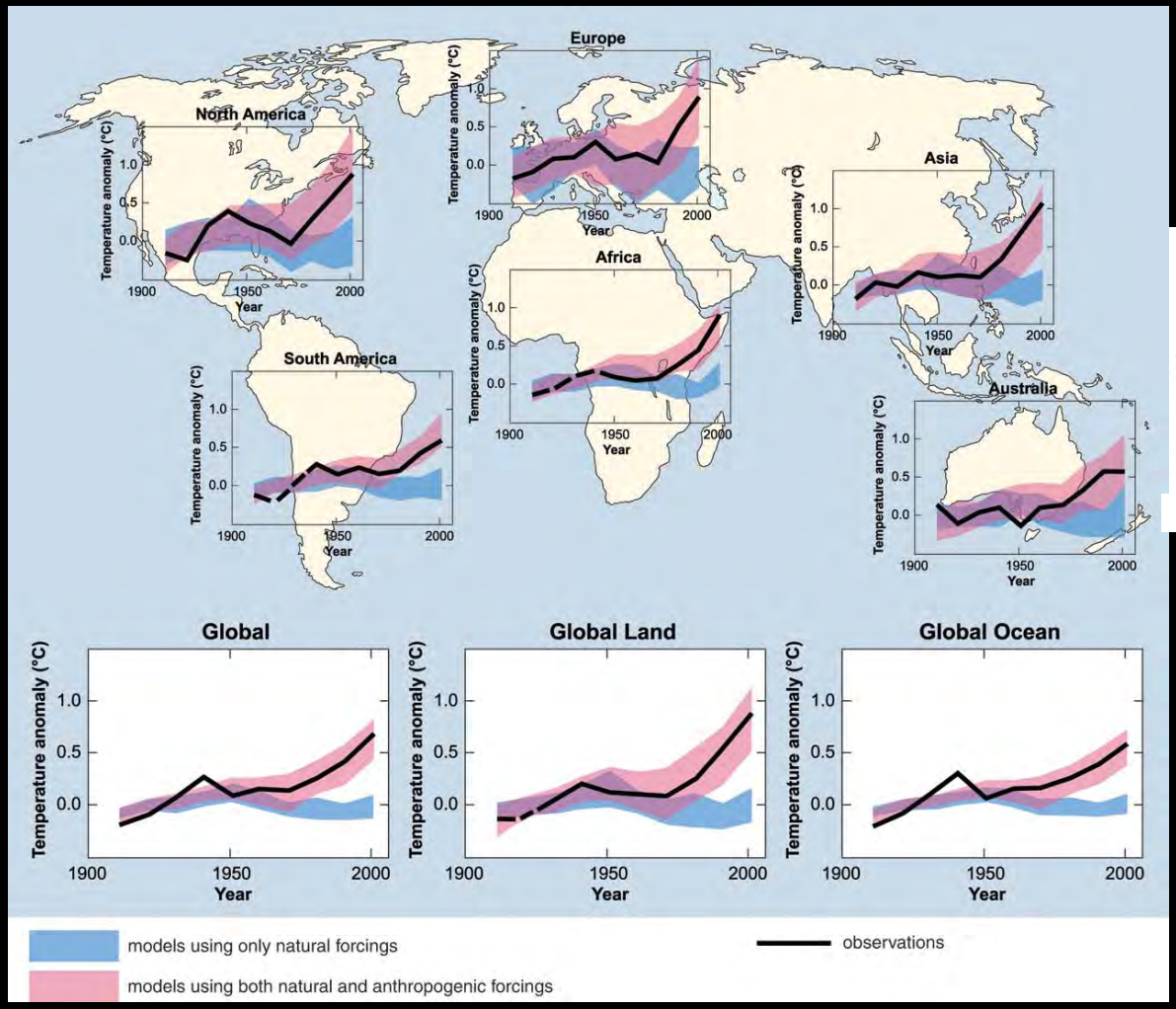
A Symphony of Forces

- Climate changes over time, often in recurring patterns or cycles
- Cycles are nested: annual, decadal, century, and millennial scales
- Different physical mechanisms drive different cycles
- Changes in climate regimes can be:
  - gradual, directional
  - episodic, reversible
  - extreme events, abrupt
  - chaotic

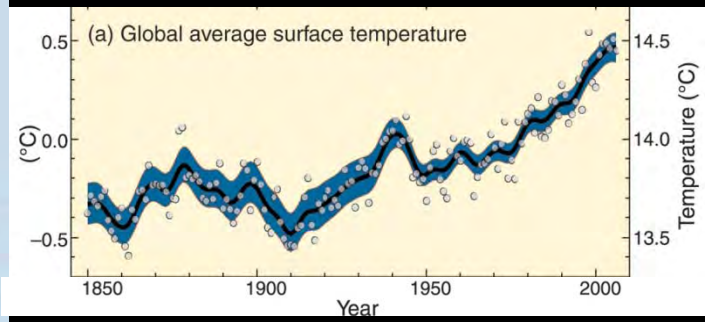


Anthropogenic Climate Change is Superimposed on Natural Climate Forces

Recall this allowed IPCC scientists to discern a greenhouse gas effect



20^{th} C:
+ 0.7°C

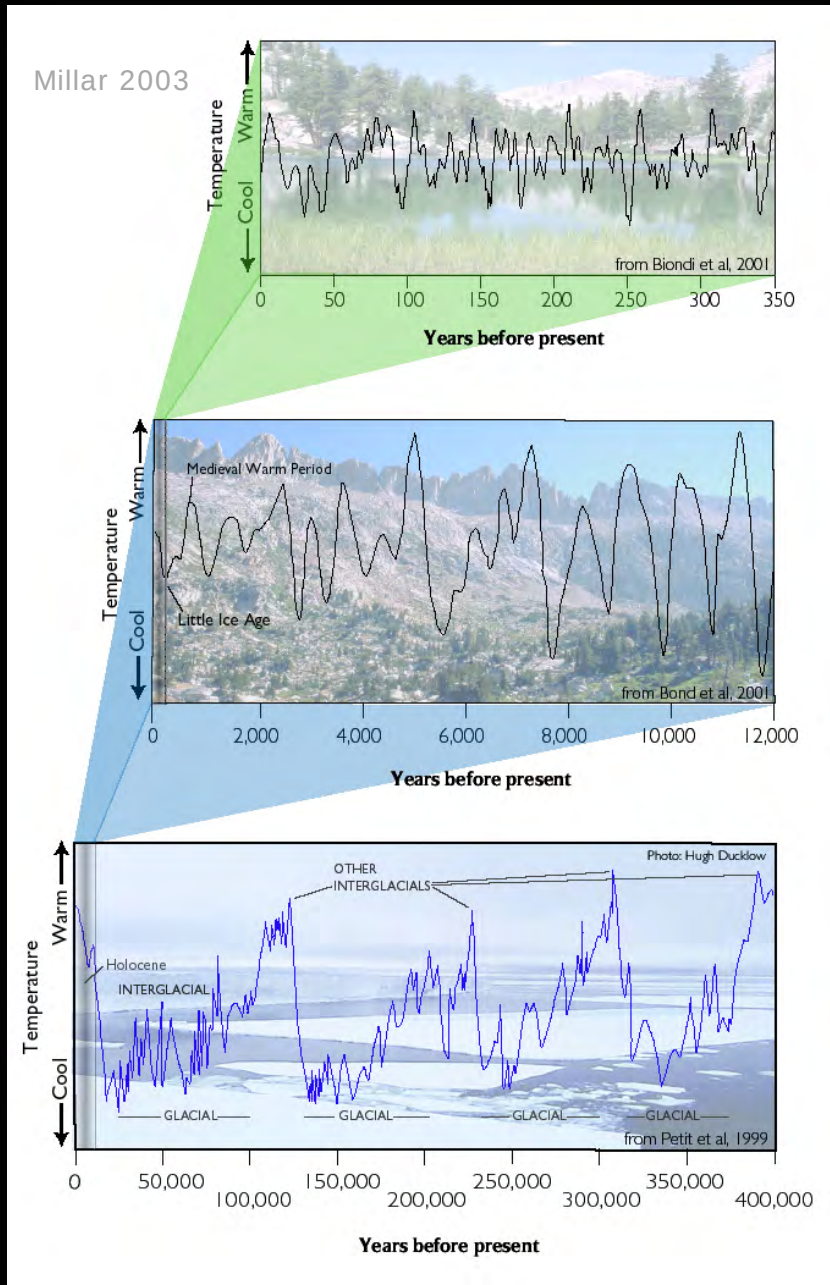


IPCC 2007
Fourth Assessment Report

Climate Change as an Ecosystem Driver:

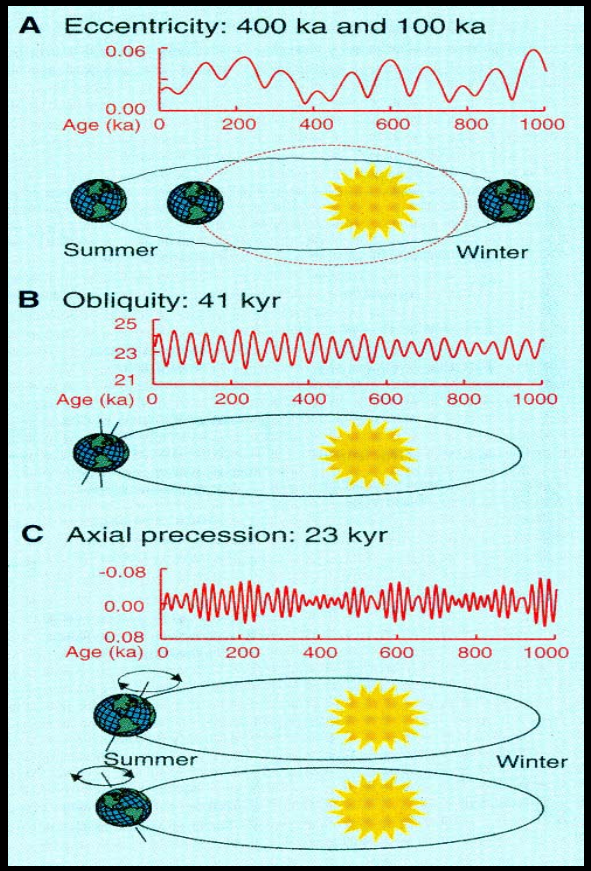
A Cacophony of Responses

- Species move
- Species evolve
- Associations re-assemble
- Abundances change
- Health, structure, productivity changes
- Disturbance regimes change
- Individuals acclimate
- Populations extirpate; species go extinct

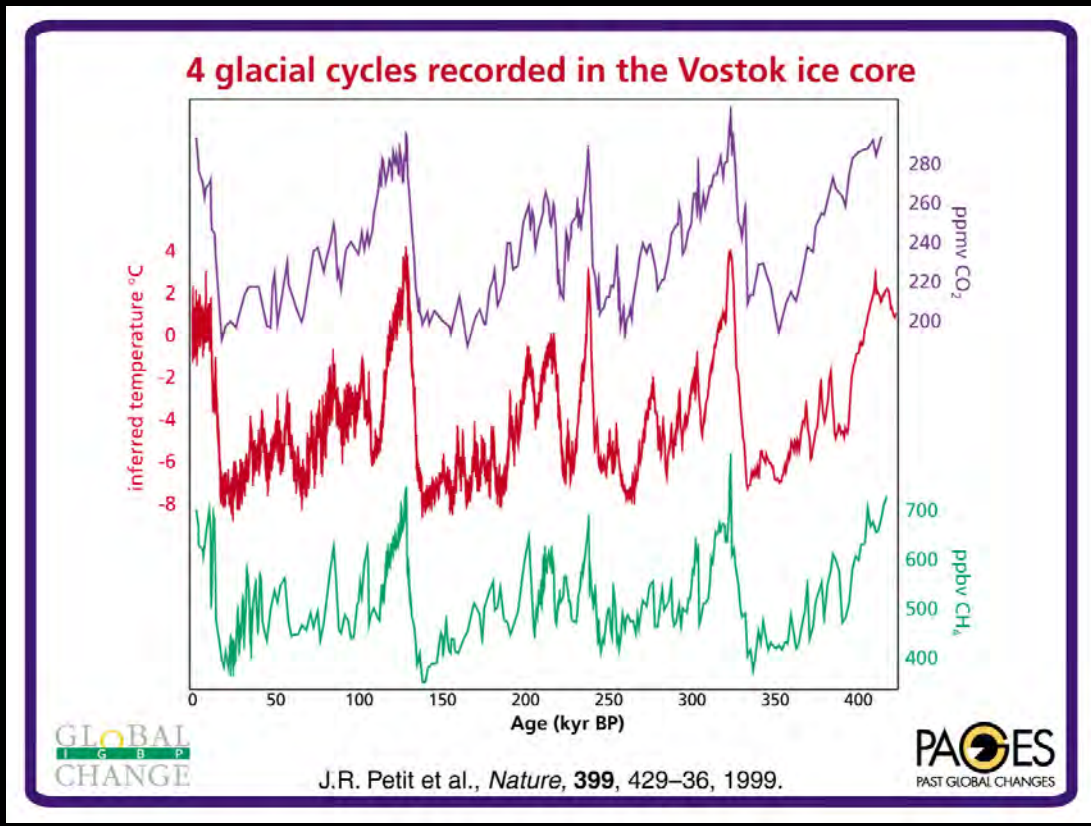


1. Glacial-Interglacial Cycles (10,000-100,000 yr periods)

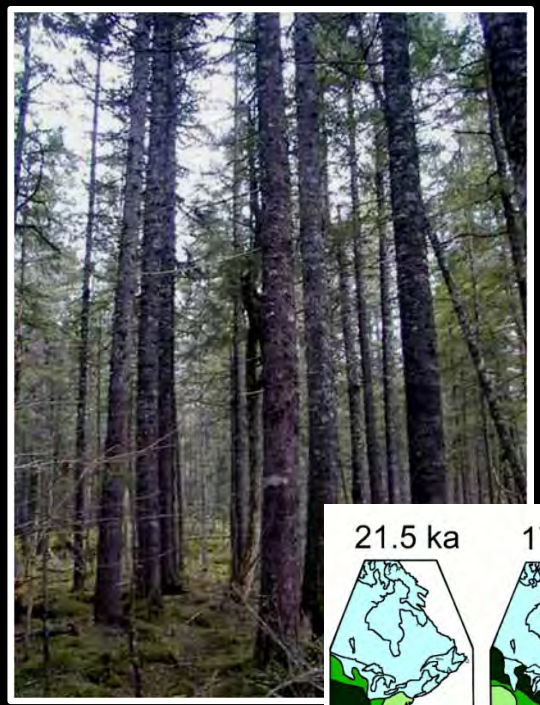
* 6°-10°C (10°-18°F) global temperature differences
* CO_2 & CH_4 also cycle
* Caused by earth's changing proximity to sun



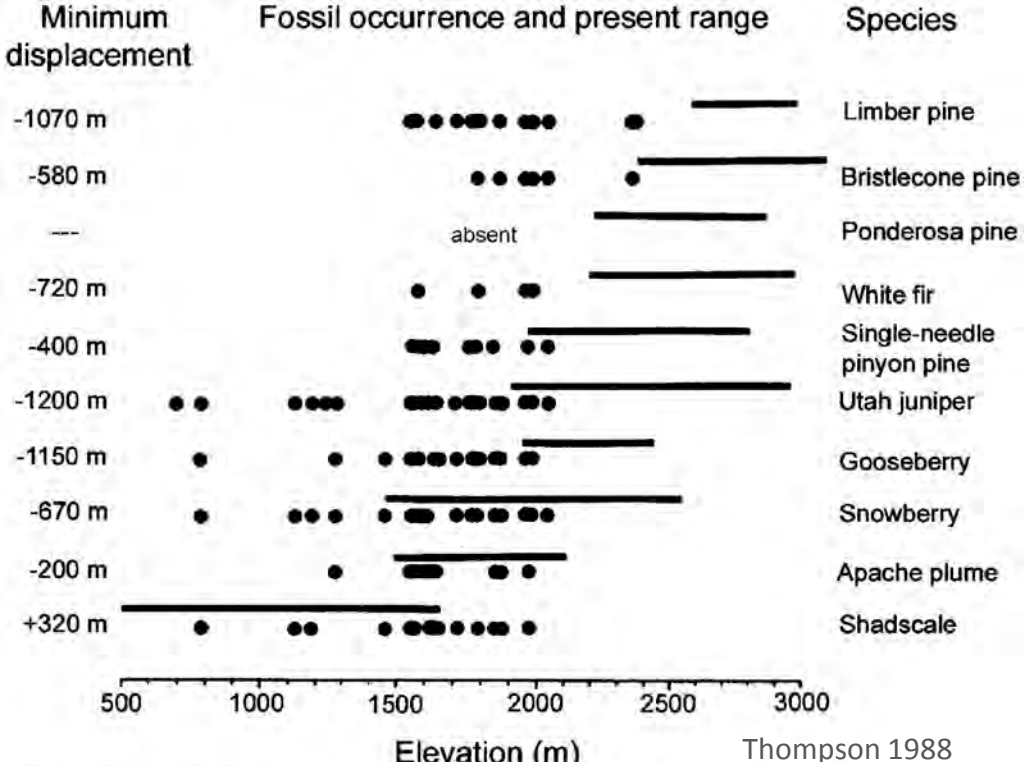
Zachos et al. 2006



Forest Responses to Millennial Cycles

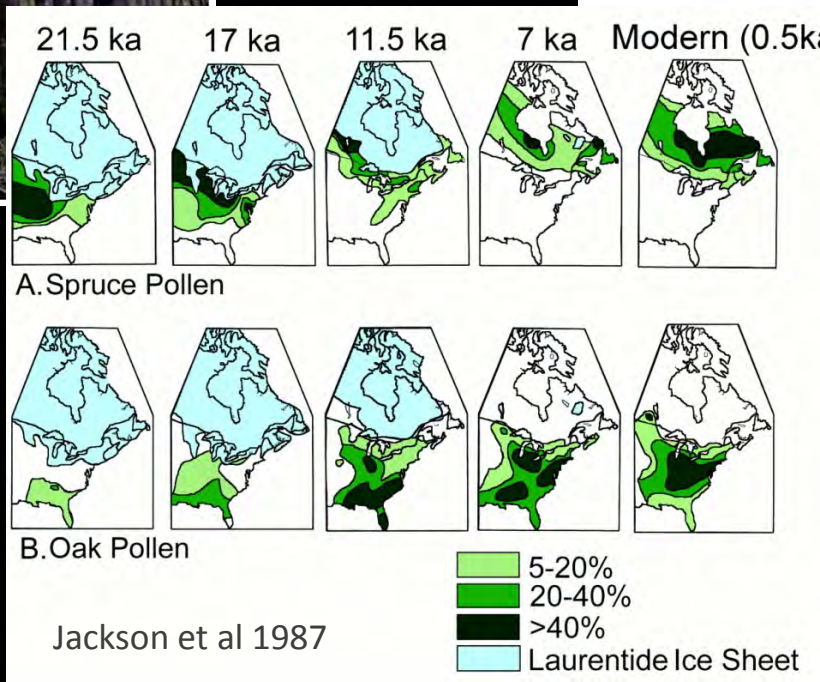


Mountain Regions



Thompson 1988

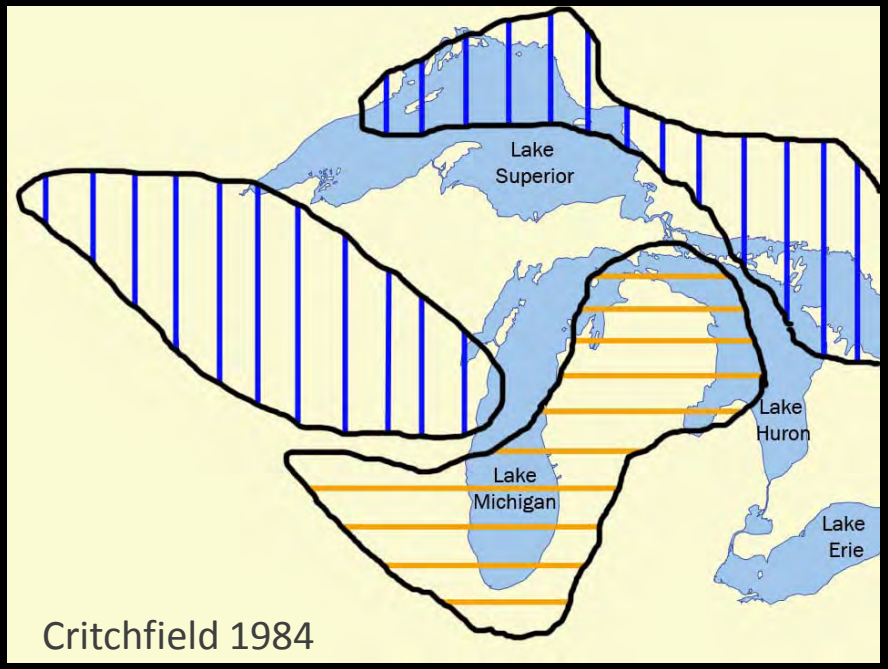
Low Relief Regions



Jackson et al 1987

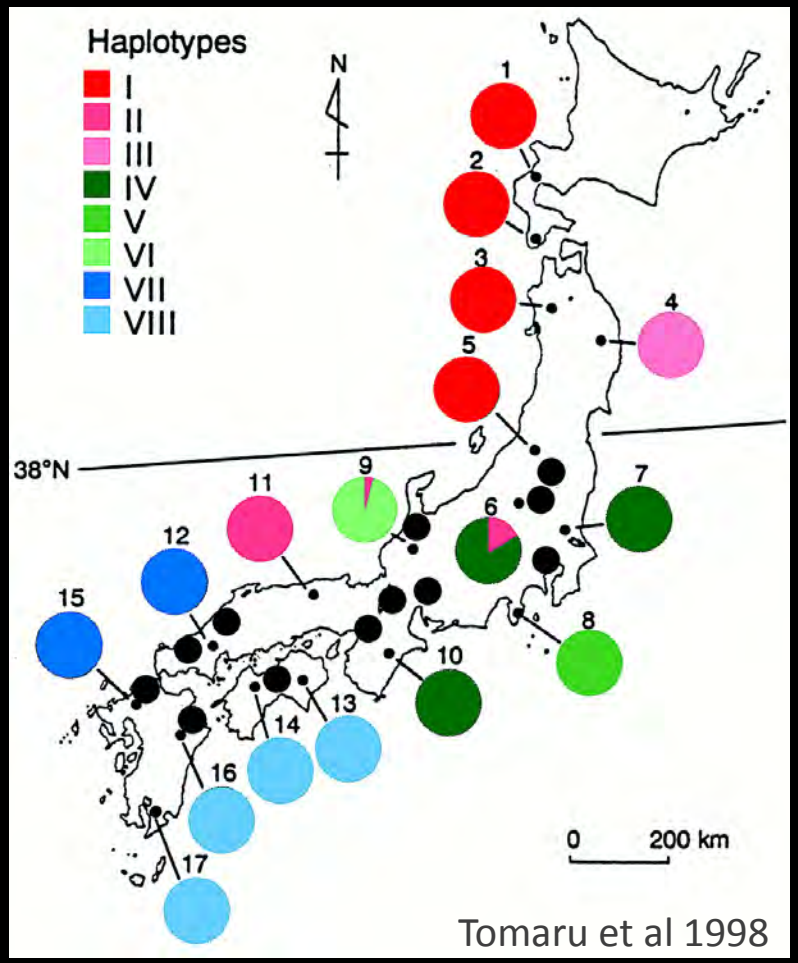
Enduring Changes in Genetic Diversity

Jack pine
Pinus banksiana



Critchfield 1984

Japanese Beech, *Fagus crenata*



Tomaru et al 1998

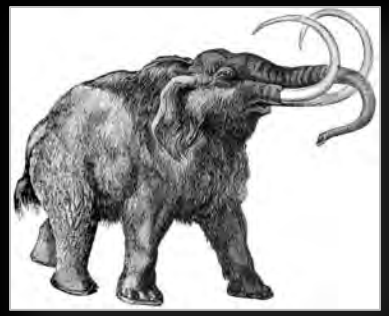
Abrupt Changes Occur E.g., End of Last Glacial Period

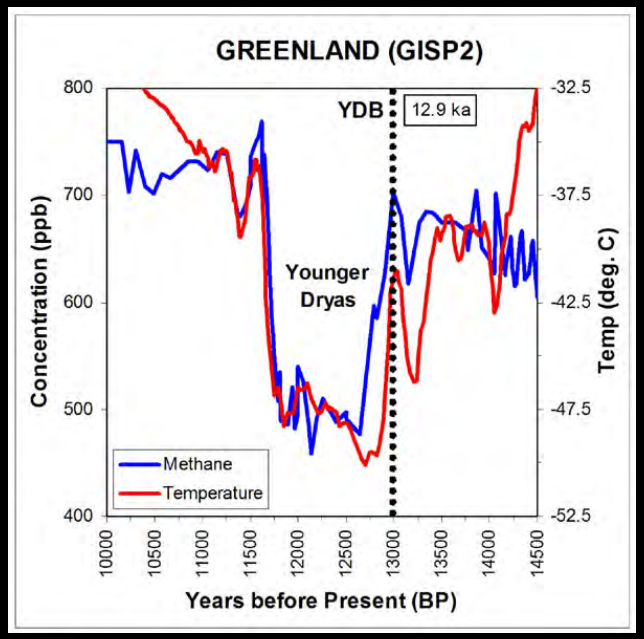
Greenland Ice Core

Global climate system re-organized in 1-3 yrs

North American Warming

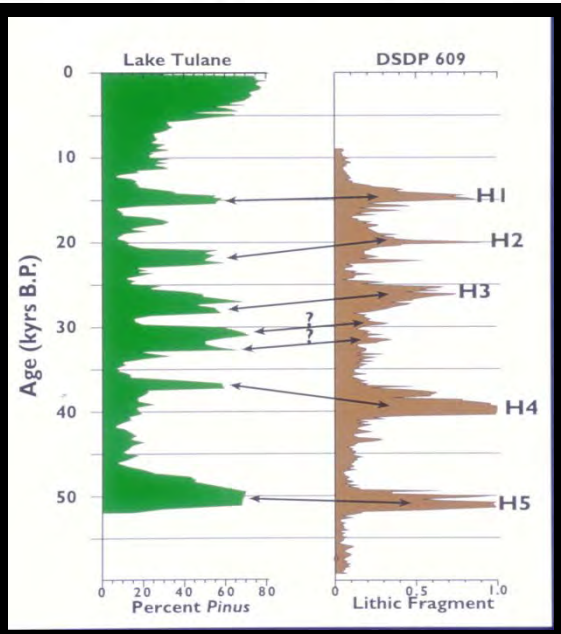
Shifts of 3-20°C in 50-75 yrs





Dramatic Changes in North American Forests in Less than 100 yrs

- Replacement of forest types
- Changes in fire regimes
- Extinction of megafauna & disappearance of Clovis humans *"occurred in 100 years, perhaps much less…"*

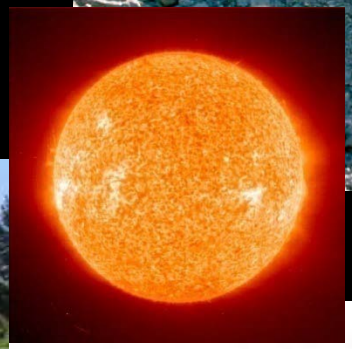


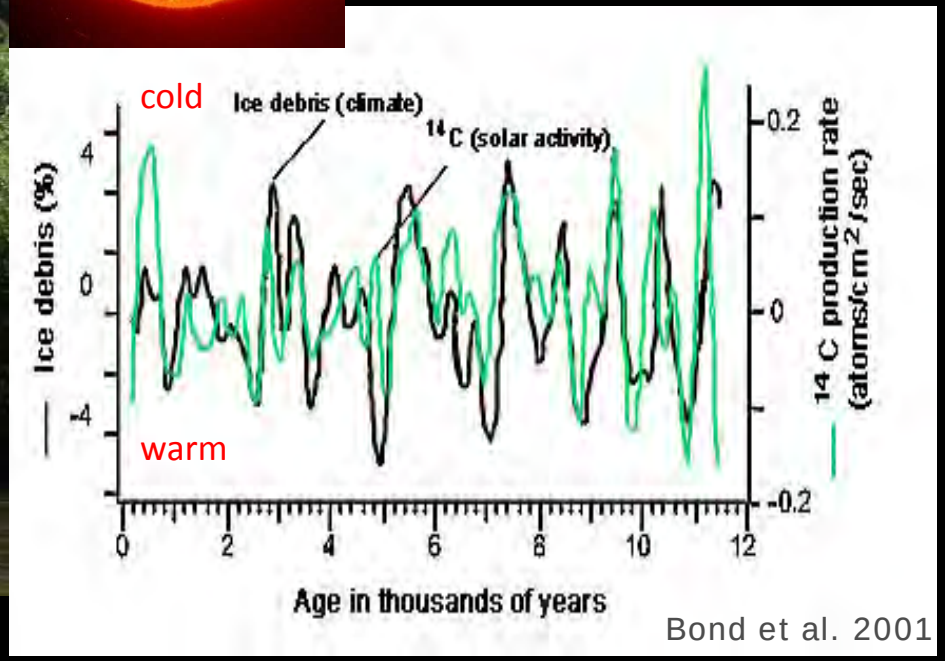
Pine – Oak Shifts, Florida

Grimm 1993, Peteet 2000, Haynes 2007, Steffenson et al 2008

2. Century-Scale Cycles (200-1,000 yr periods)

* 1°-3°C (1.8° – 5.4F°) mean changes in global temperature
* Triggered by changes in Sun's activity
* Variably expressed in different regions





Bond et al. 2001

Century-Scale Vegetation Response

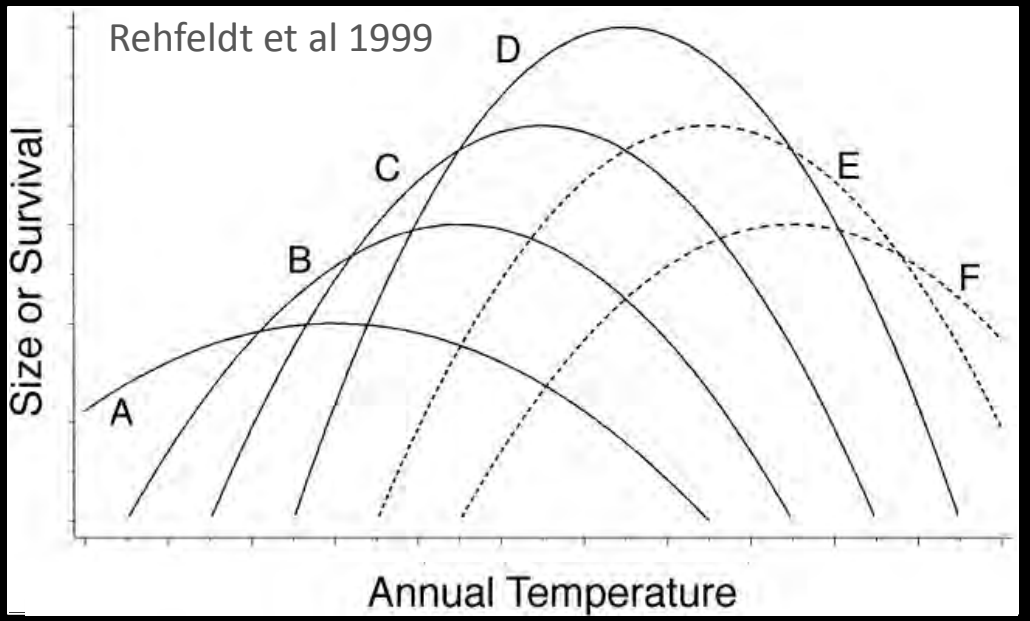
WhiteWing Mtn, CA, 3105m
Medieval Deadwood Forest
900-1350 CE

Whitebark pine, Lodgepole pine , Jeffrey pine, Western white pine, Sugar pine, Mountain hemlock

Species grew that are not currently native to this elevation or region

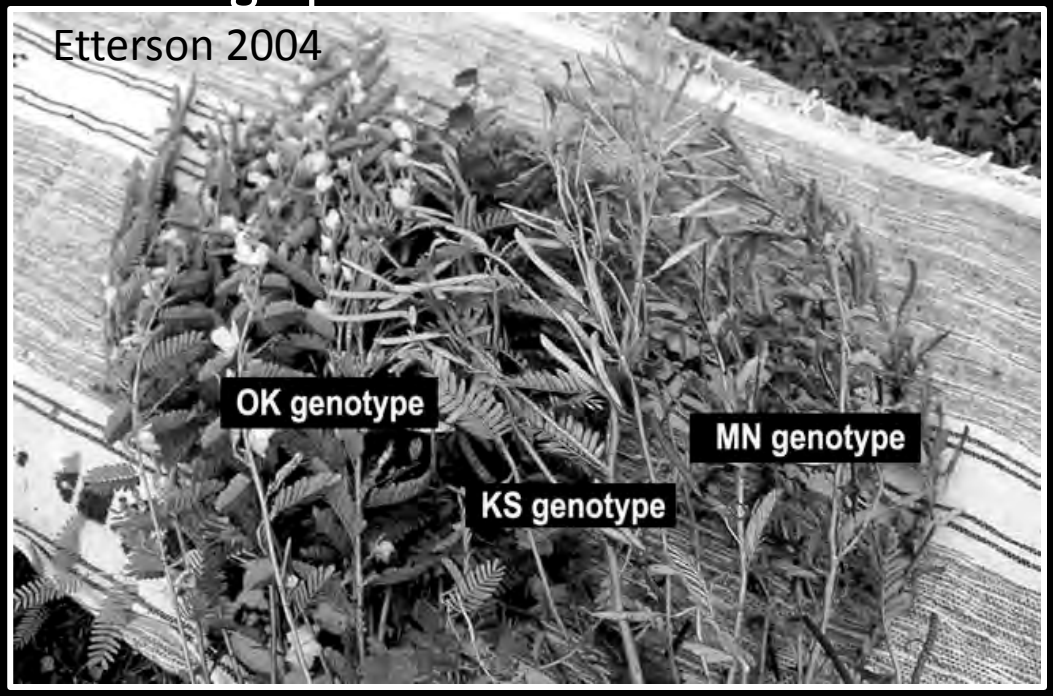
Millar et al. 2006

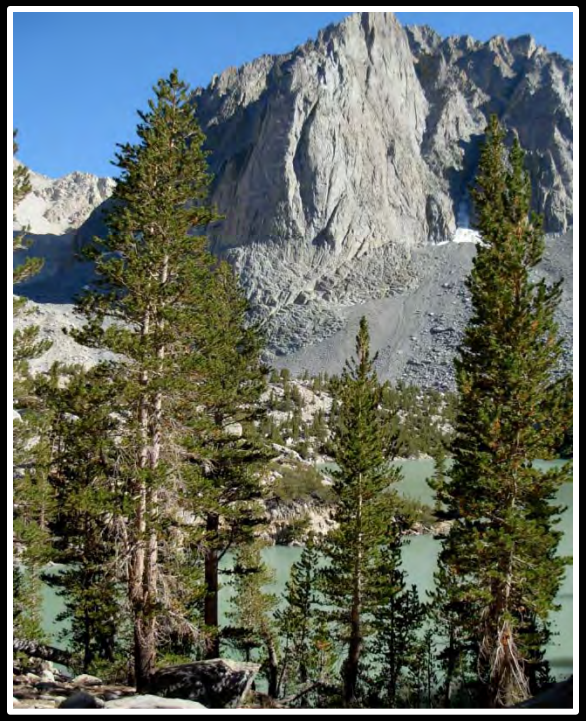
Changes in Genetic Diversity



Lodgepole pine temperature races

Phenology differences,
Partridge pea
Etterson 2004





3. Decadal & Annual-Scale Cycles

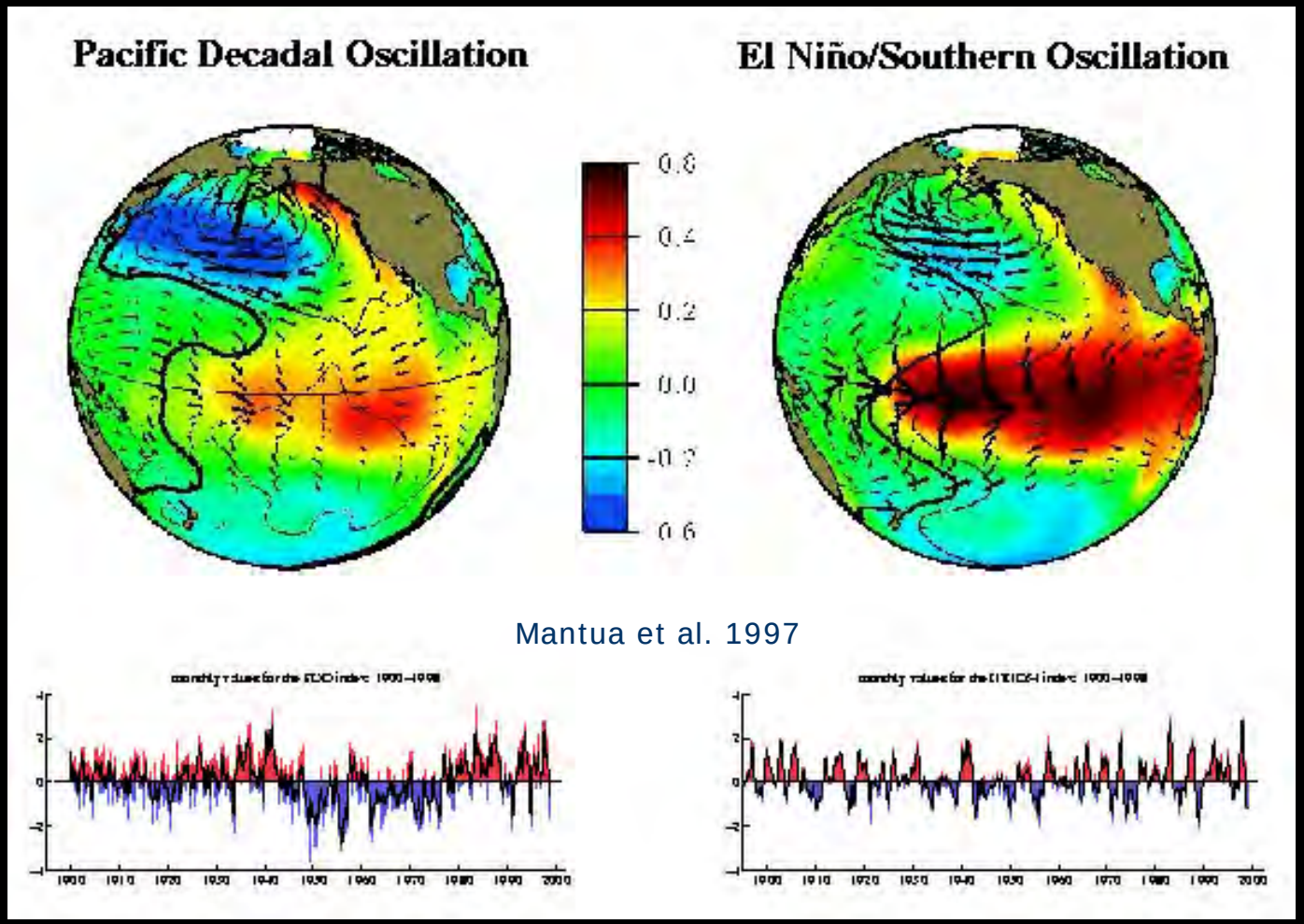
(2 to 45 yr periods)

* E.g. Pacific Decadal Oscillation

25 - 45 yr cycle

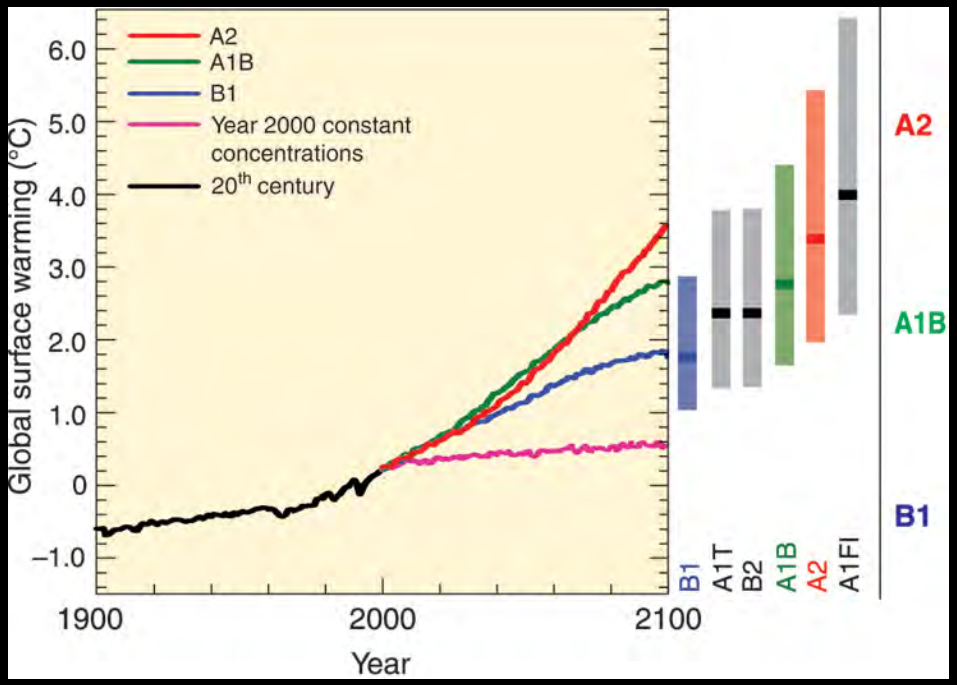
* El Niño/La Niña

2 - 8 yr cycle



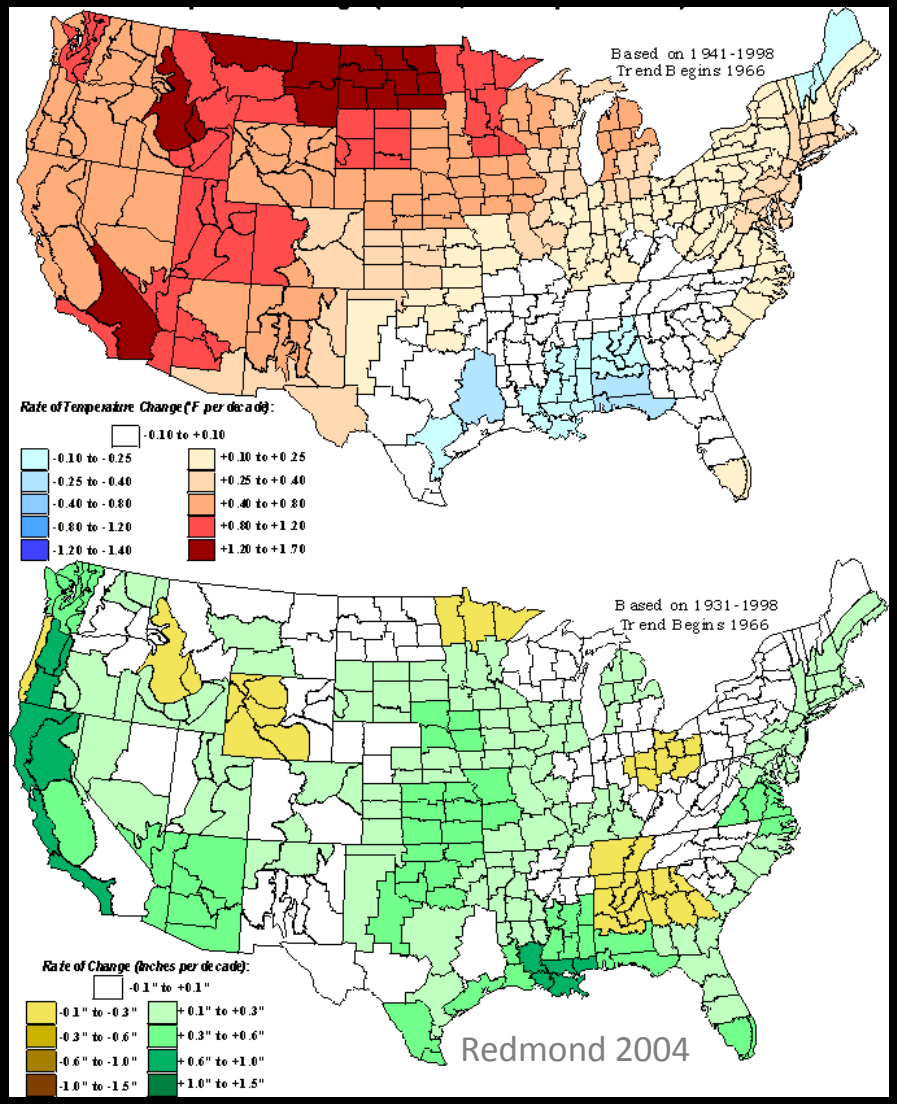
Anthropogenic Forcing; Annual to Multi-Decadal

1-4°C global increase in temp projected for 2100



* GHG expression becomes increasingly variable at regional & local scales and over shorter times (= NF, LMP scales)

* Interacts significantly with natural forces



Temp & Precip Changes: 1966-2004

Ecosystem Responses

Changes in demography, type conversions, range extensions

Changes in health & productivity, genetic diversity, disturbance regimes, individual acclimation

Multiple Stresses

Climatic *Interactions* Yield Surprises

Great Lakes Ice Cover

Wang et al. 2010

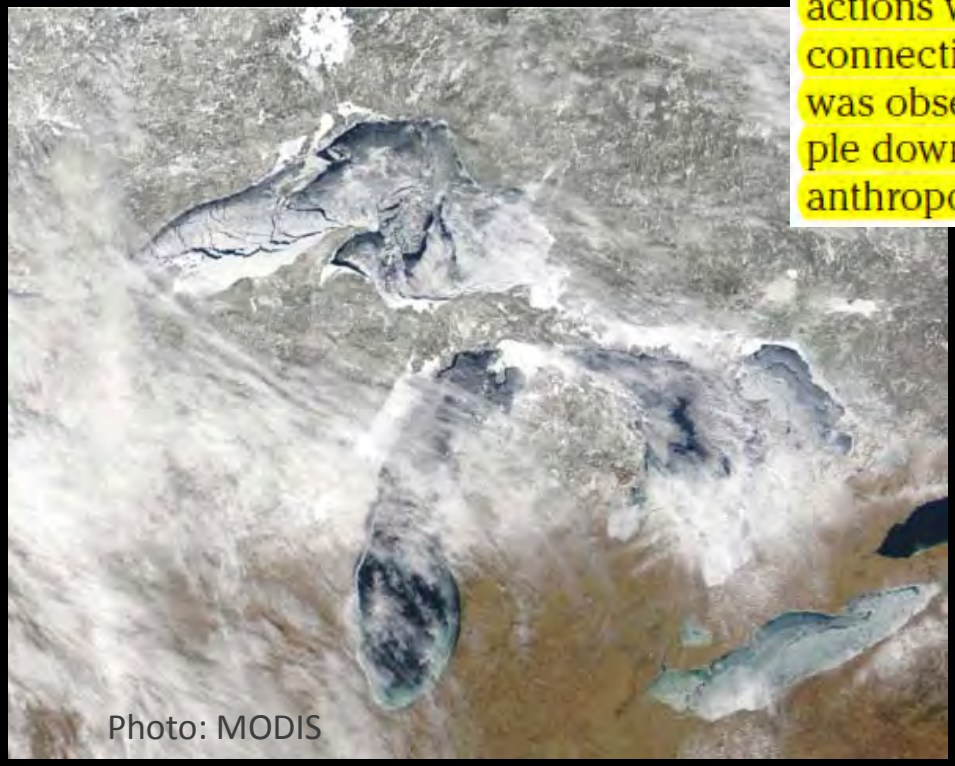


Photo: MODIS

The drastic changes in lake ice cover over the past few decades imply that significant natural variability, caused by interactions with remote climate patterns (teleconnections), played a large role in what was observed and overshadowed the simple downward trend of lake ice caused by anthropogenic climate warming.

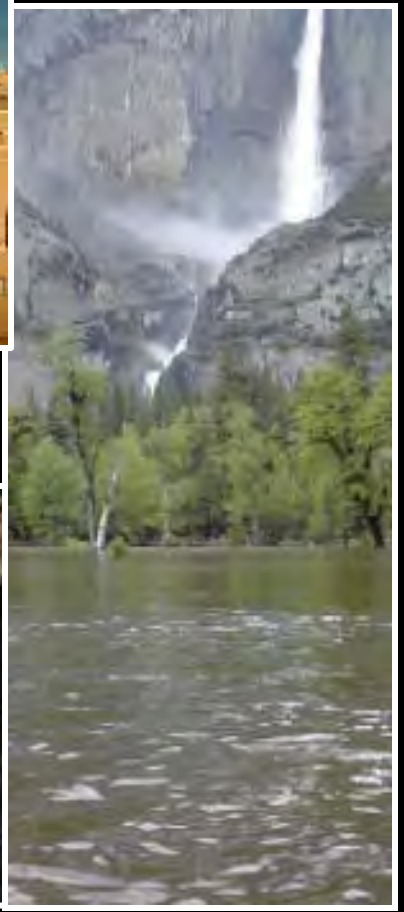
Severe Wildfire in the West

Schoennagel et al. 2006

Photo: L. Schoennagel

"70% of large fires in Rocky Mountain National Park burned during La Niña events that coincided with a negative PDO"

Extreme & Abrupt Events Trigger Significant and Long-Lasting Ecological Changes



Local Climates and Responses can be *Decoupled* from Regional Trends

Cold-air pooling, topographic effects, microclimatic circulation

Millar & Westfall 2010

Implications to Resilience, Restoration, and Conservation

Climate is a fundamental architect of ecosystem change

Native species ranges are highly dynamic (ESA, invasive species)

Ecosystem sustainability involves turnover of species diversity and changes in function (NFMA)

Resilience involves “maintaining the dynamic capacity of an ecosystem to respond to change” Costanza et al 1993

FORESTS WITH A FUTURE

Historical conditions are increasingly poor references for restoration

Human land-use combined with societal demands create novel challenges for adaptation