“Under warming climates, species adapt, move, or die”

A globally coherent fingerprint of climate change impacts across natural systems

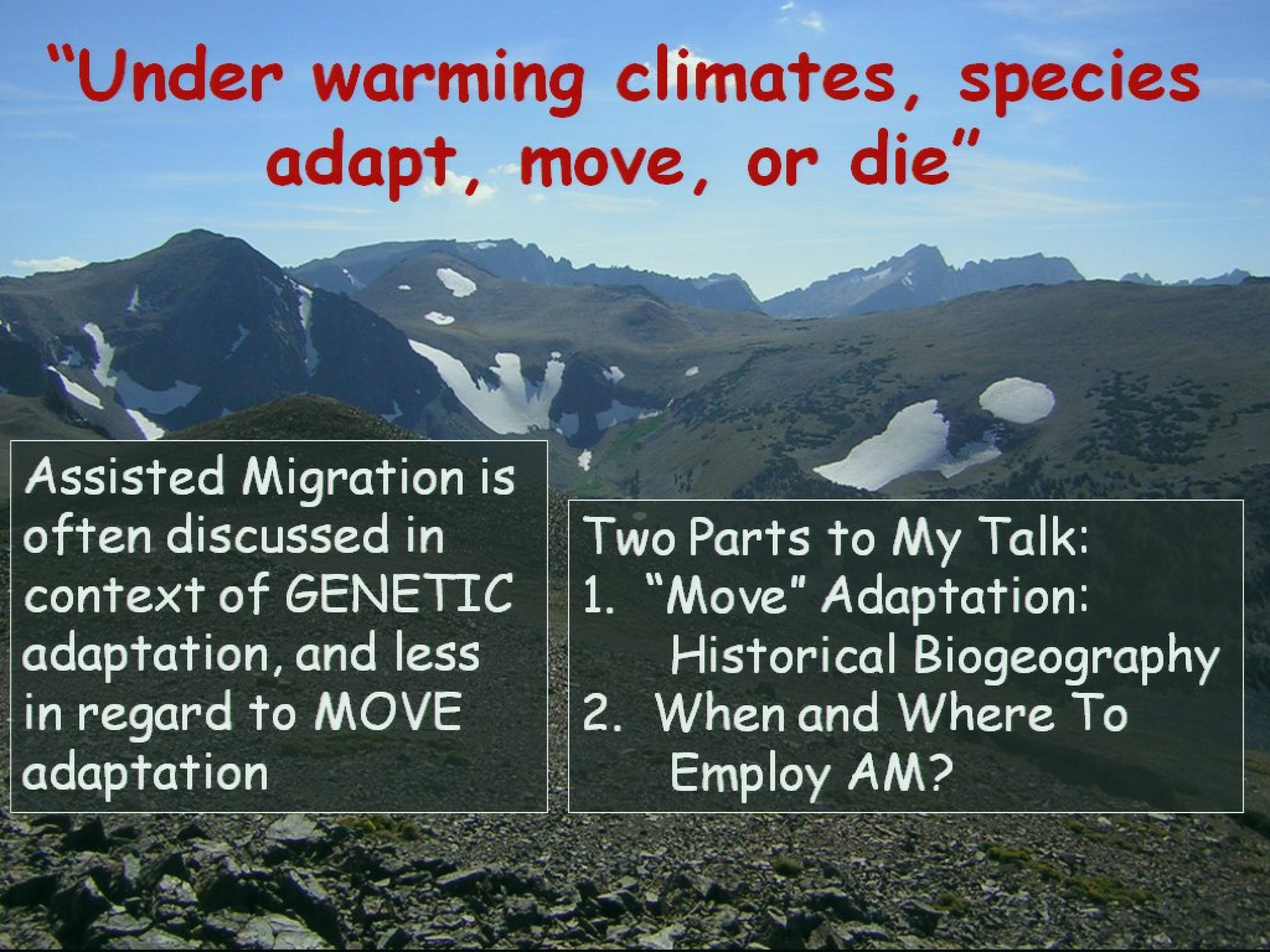
Camille Parmesan* & Gary Yohe†

NATURE | VOL 421 | 2 JANUARY 2003 |

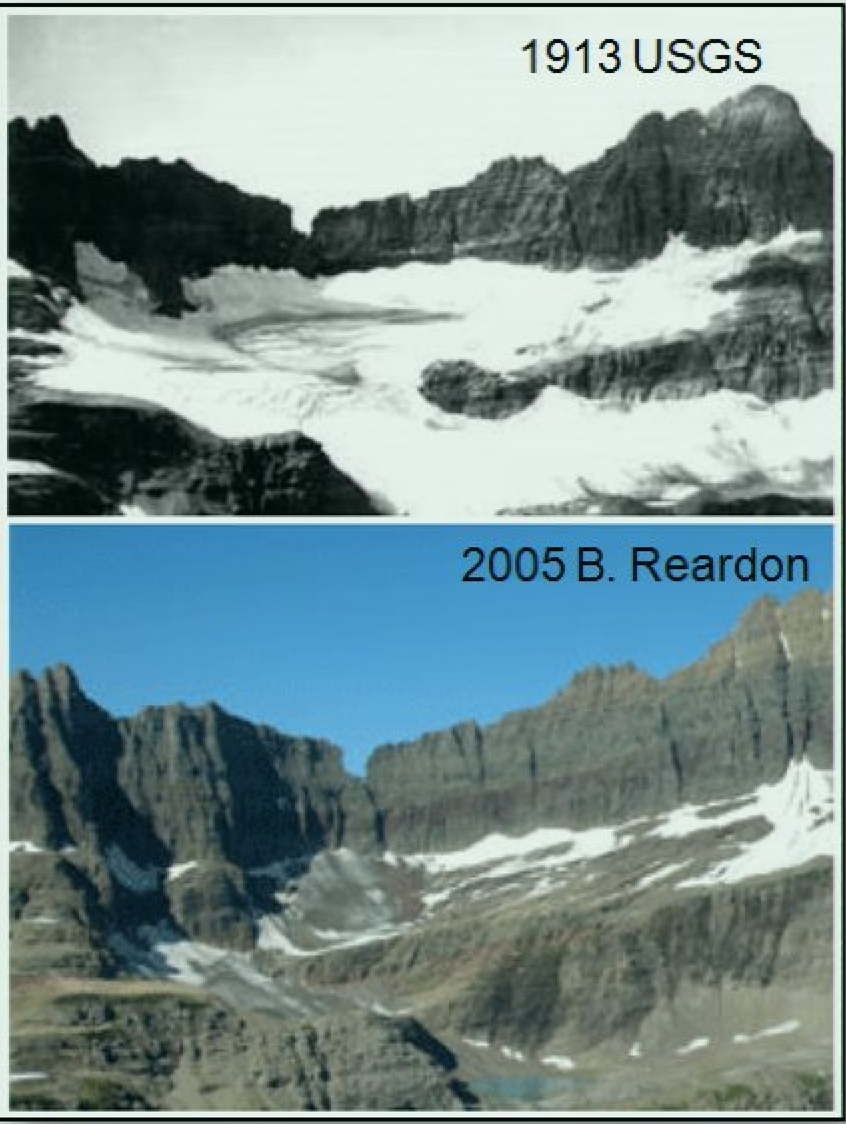
A Significant Upward Shift in Plant Species Optimum Elevation During the 20th Century

J. Lenoir,[1]* J. C. Gégout,[1] P. A. Marquet,[2,3,4] P. de Ruffray,[5] H. Brisse[6]

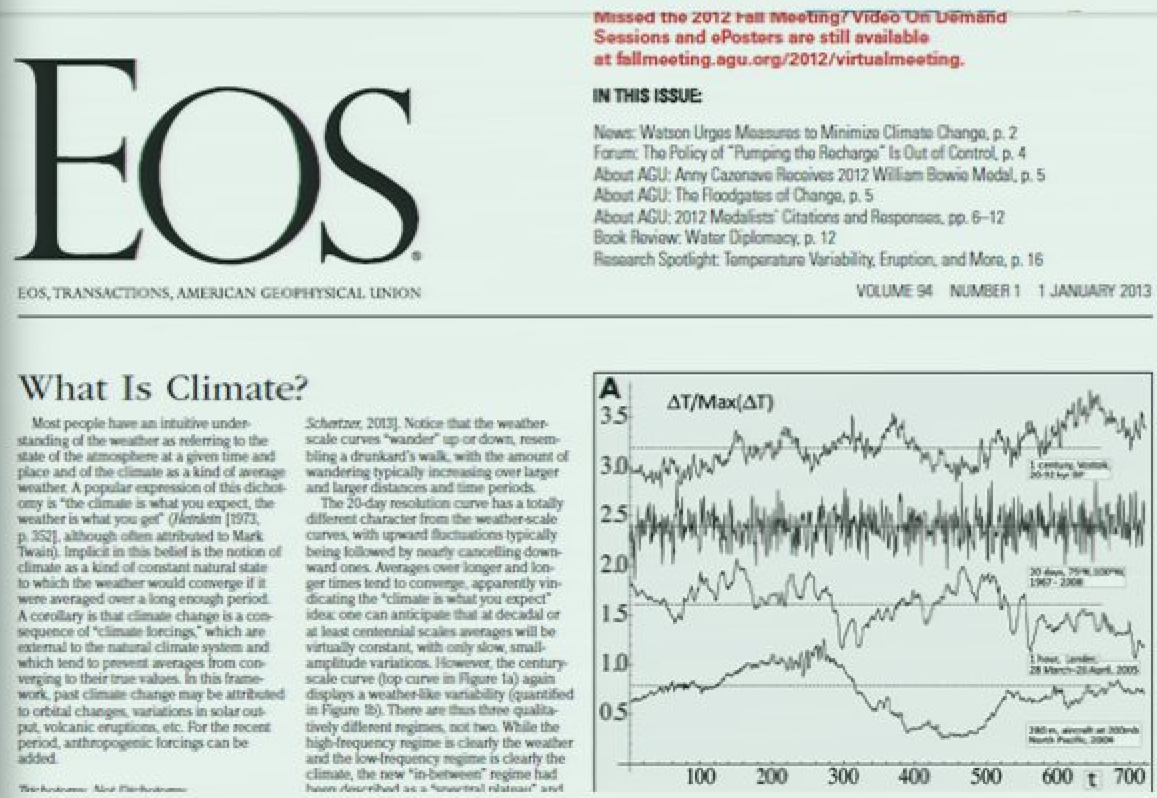
27 JUNE 2008 VOL 320 SCIENCE


"Under warming climates, species adapt, move, or die"
Assisted Migration is often discussed in context of GENETIC adaptation, and less in regard to MOVE adaptation
Two Parts to My Talk:
1. "Move" Adaptation: Historical Biogeography
2. When and Where To Employ AM?

Historical Biogeography: When and Where Did Species Move Naturally?



Climate Changes → Species Respond



Missed the 2012 Fall Meeting? Video On Demand Sessions and ePosters are still available at fallmeeting.agu.org/2012/virtualmeeting.

EOS

IN THIS ISSUE:

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION
VOLUME 94 NUMBER 1 1 JANUARY 2013

What Is Climate?

Most people have an intuitive understanding of the weather as referring to the state of the atmosphere at a given time and place and of the climate as a kind of average weather. A popular expression of this dichotomy is "the climate is what you expect, the weather is what you get" (*Heinlein* [1973, p. 352], although often attributed to Mark Twain). Implicit in this belief is the notion of climate as a kind of constant natural state to which the weather would converge if it were averaged over a long enough period. A corollary is that climate change is a consequence of "climate forcings," which are external to the natural climate system and which tend to prevent averages from converging to their true values. In this framework, past climate change may be attributed to orbital changes, variations in solar output, volcanic eruptions, etc. For the recent period, anthropogenic forcings can be added.

Schertzer, 2013]. Notice that the weather-scale curves "wander" up or down, resembling a drunkard's walk, with the amount of wandering typically increasing over larger and larger distances and time periods.

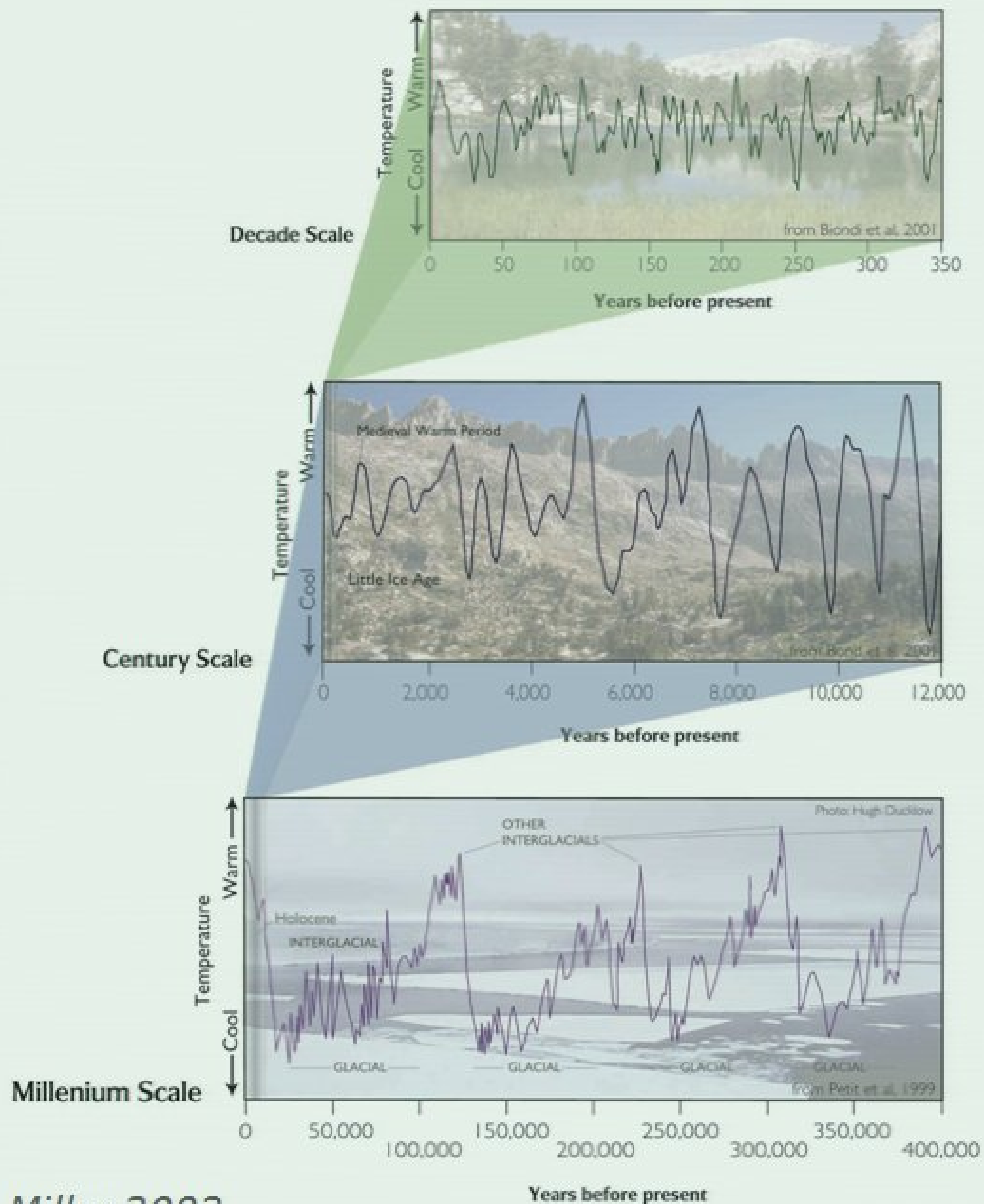
The 20-day resolution curve has a totally different character from the weather-scale curves, with upward fluctuations typically being followed by nearly cancelling downward ones. Averages over longer and longer times tend to converge, apparently vindicating the "climate is what you expect" idea: one can anticipate that at decadal or at least centennial scales averages will be virtually constant, with only slow, small-amplitude variations. However, the century-scale curve (top curve in Figure 1a) again displays a weather-like variability (quantified in Figure 1b). There are thus three qualitatively different regimes, not two. While the high-frequency regime is clearly the weather and the low-frequency regime is clearly the climate, the new "in-between" regime had

History & Climate: The Bigger Picture

Earth's Natural Climate System

- Climates change continually;
- Climates express at annual, decadal, century, and millennial scales;
- Different physical mechanisms drive different climate modes;
- Changes in climate regimes are:
  - gradual, directional
  - episodic, reversible
  - extreme events, abrupt
  - chaotic.

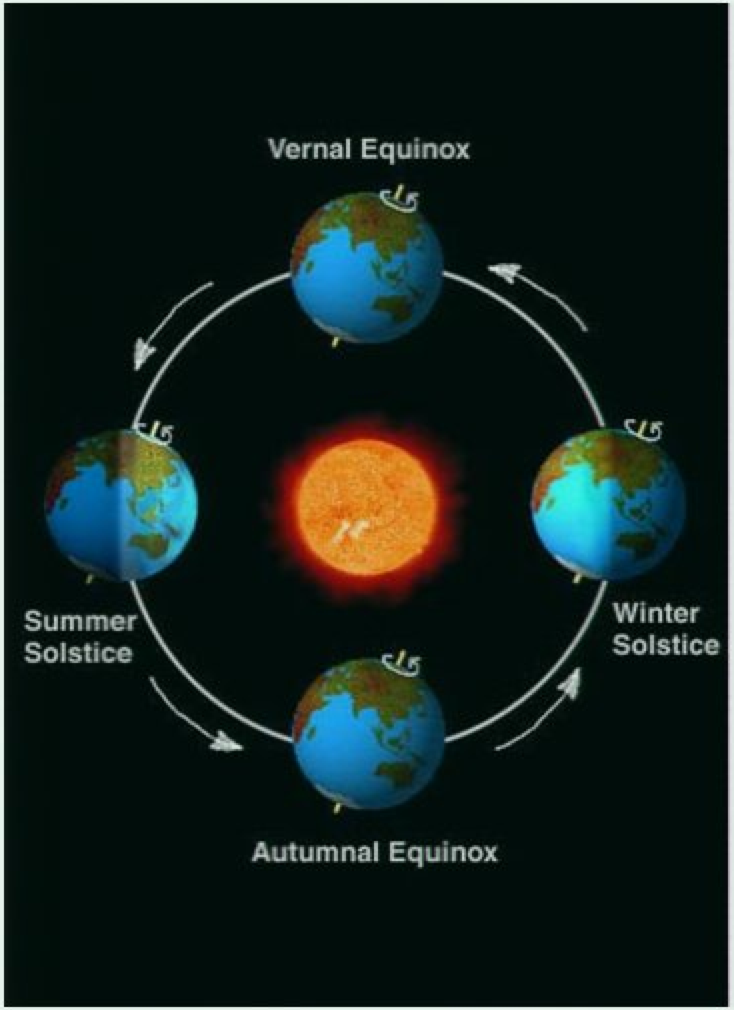
Ecosystems respond at all scales

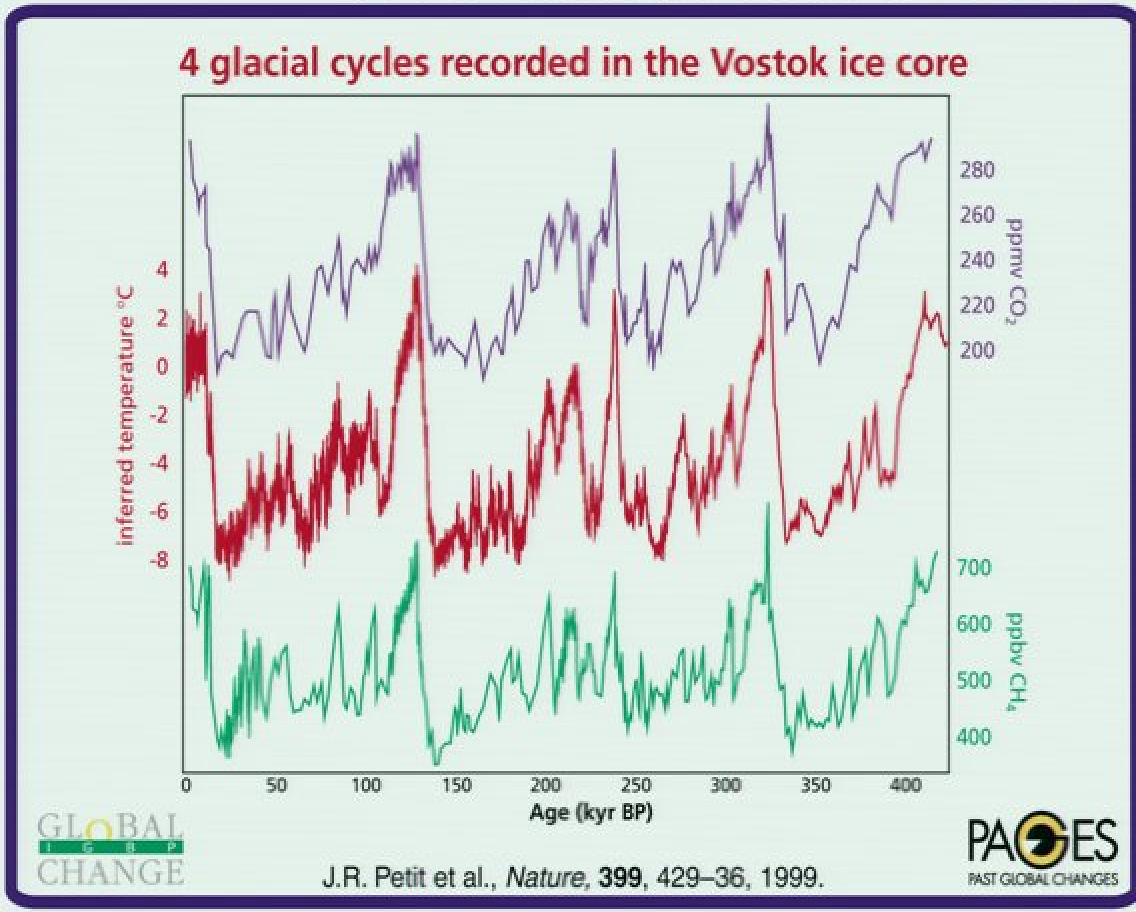


Millar 2003

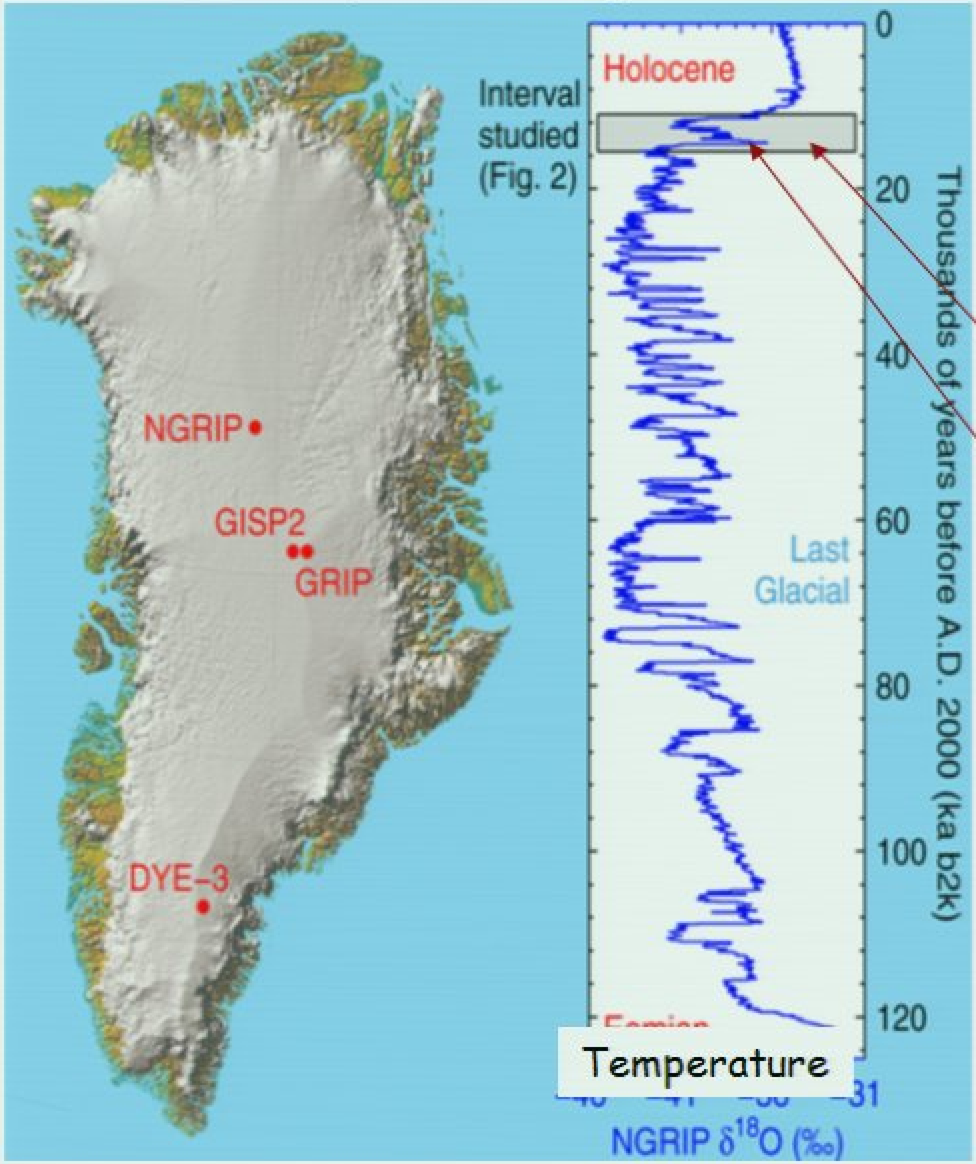
1. Glacial-Interglacial Cycles
(10,000-100,000 yr periods)

* 6°-10°C (10°-18°F) mean global temp differences
* CH_4 & CO_2 also cycle (200 to 300 ppmv)
* Driven by earth's changing relationship to sun





Climate changes were often very abrupt even at this scale



Greenland Ice Cores

Abrupt 4°C (7°F) increases in mean temperature over 1-3 yrs;

Cumulative 15°C (27°F) warming over 40 yrs;

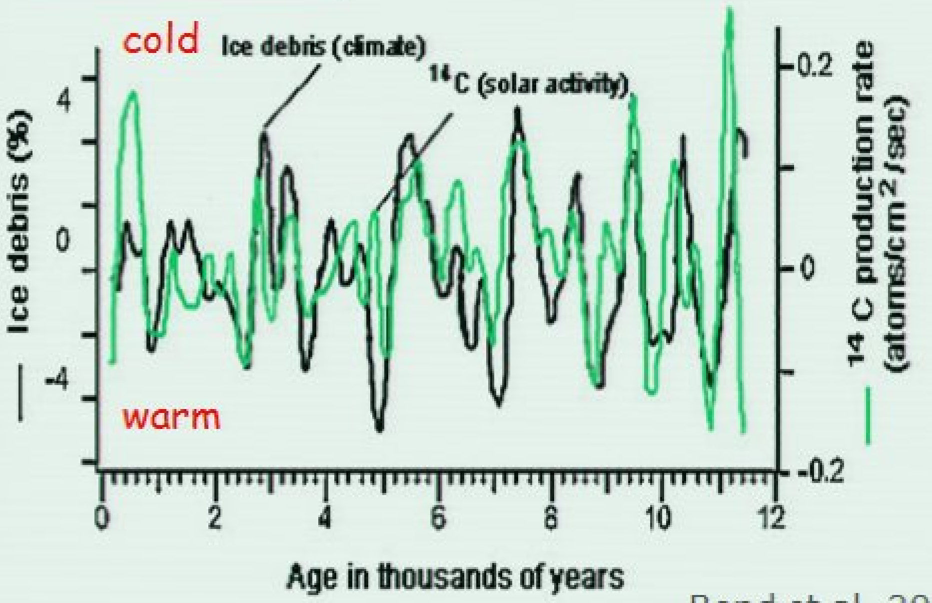
"Re-organization of the climate system"

Taylor et al. 1997; Steffenson et al. Science 2008

2. Century-Scale Cycles

(200-1000 yr periods)

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



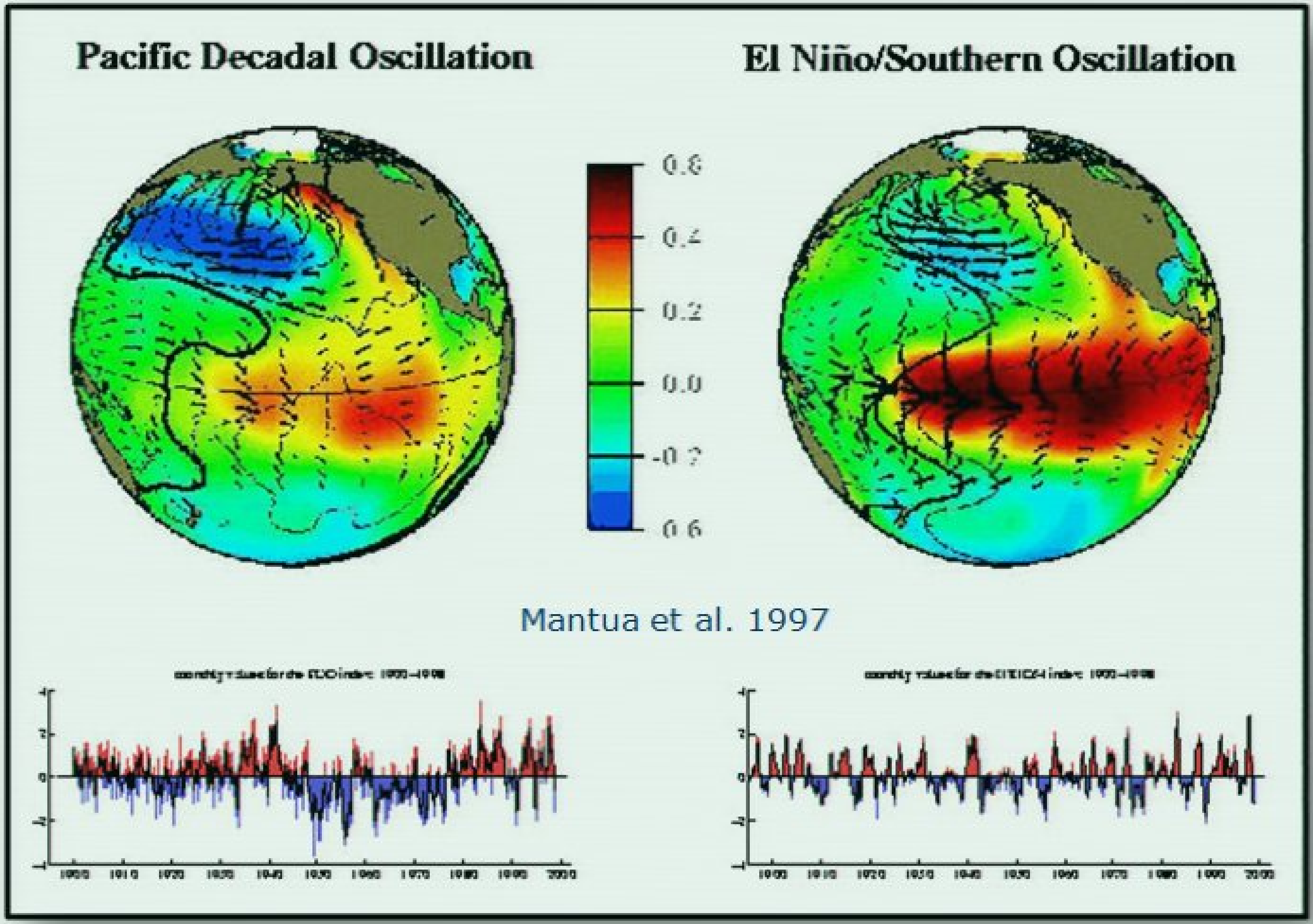
Bond et al. 2001

3. Decadal & Annual-Scale Cycles

(2 to 45 yr periods)

* Pacific Decadal Oscillation — 25 - 45 yr cycle
* El Niño/La Niña (ENSO) — 2 - 8 yr cycle

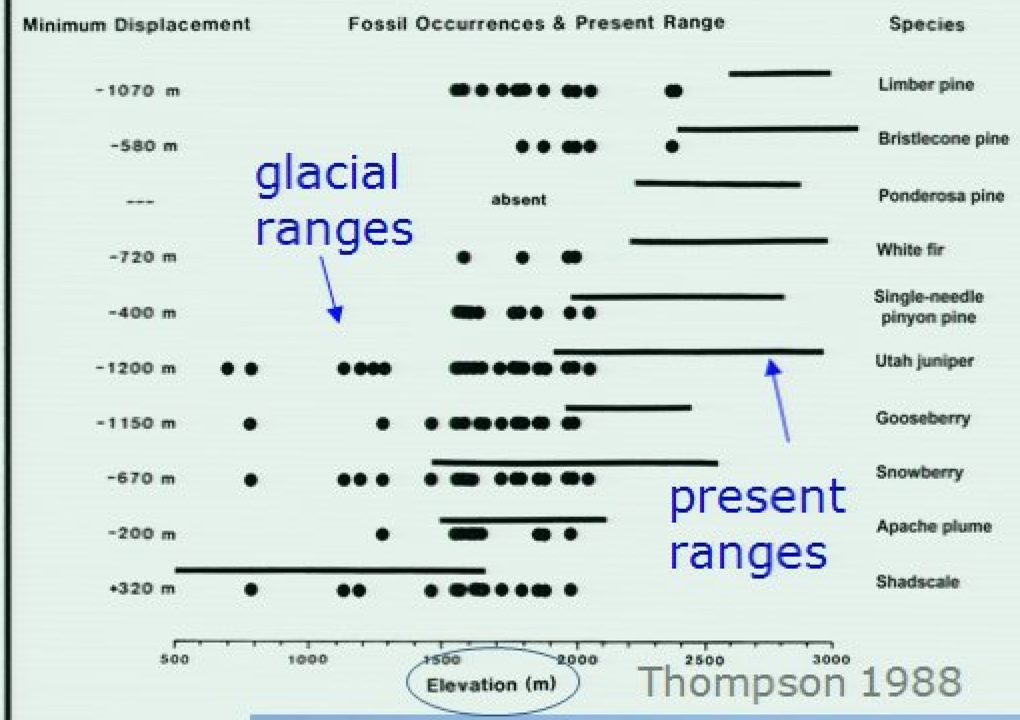
Driven by changes in ocean circulation



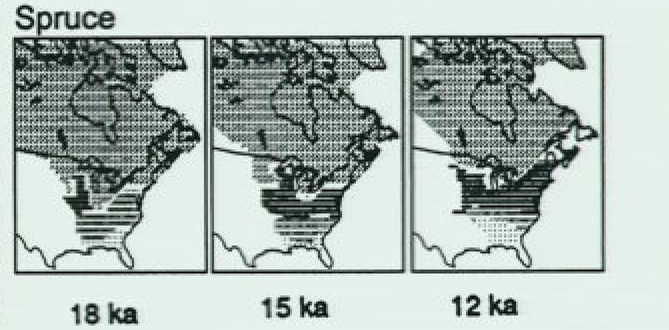
Biota Respond to Climate at All Scales

1. Glacial-Interglacial

Mountain Regions: Move 1000 m

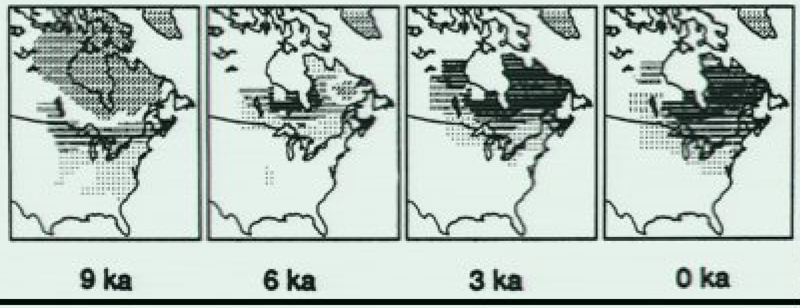


Thompson 1988



Jacobson et al. 1987

Low Relief Regions: Move 1000 km



2. Century-Scale Vegetation Response

WhiteWing Mtn, CA

Medieval Deadwood Forest

900-1350 CE

Species not currently native to this elevation or region grew on summit to 650 yrs ago

Great Basin Ranges, NV

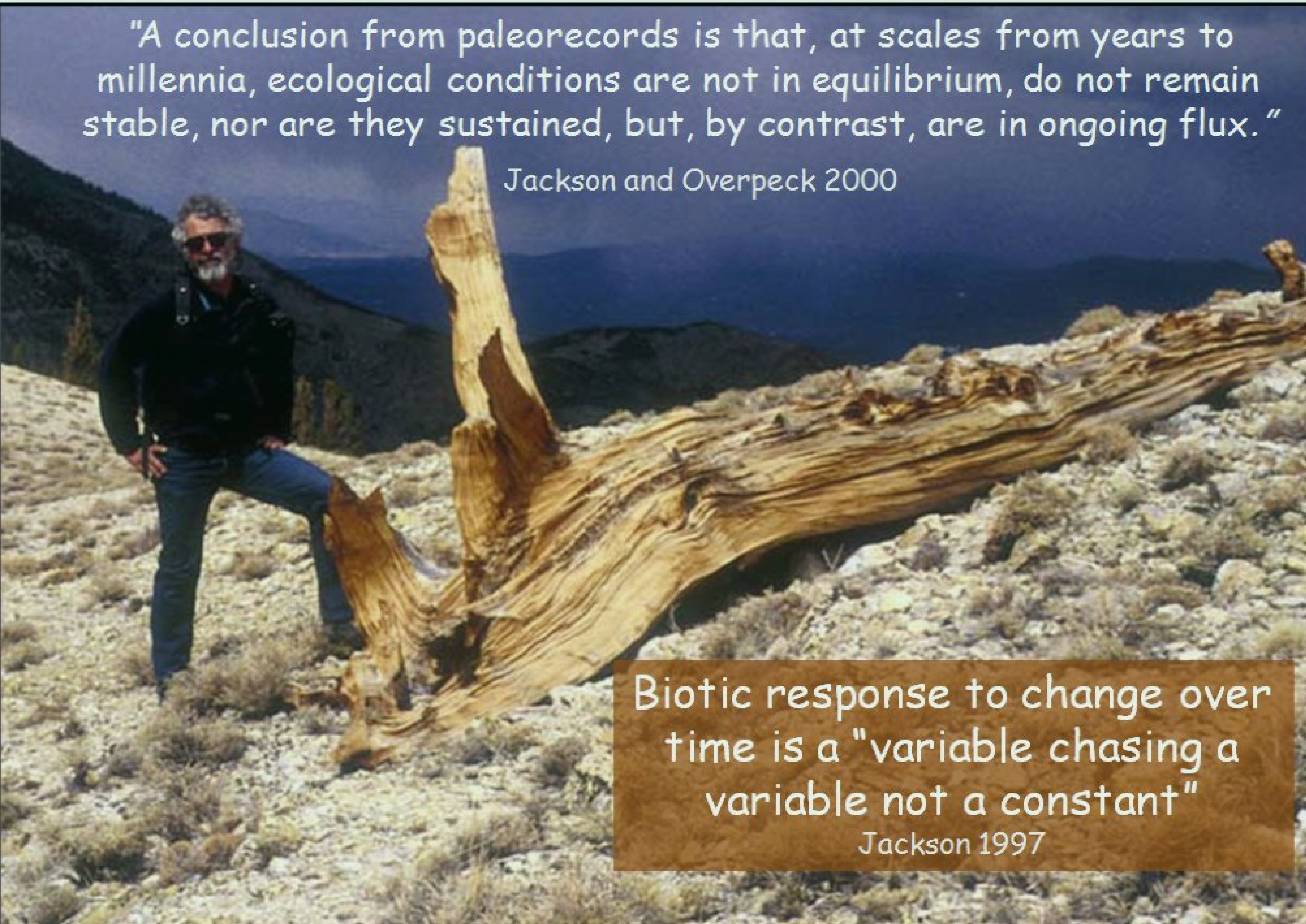
Limber pine forests winked on & off over 4000 yrs, changing in aspect not elevation

Millar et al. 2006

3. Multi-Decadal and Inter-Annual Scale Vegetation Changes

Demography, stand structure, type conversions, tree form, mortality pulses, fire regimes

Millar et al. 2004, 2007, 2012


"A conclusion from paleorecords is that, at scales from years to millennia, ecological conditions are not in equilibrium, do not remain stable, nor are they sustained, but, by contrast, are in ongoing flux."
Jackson and Overpeck 2000
Biotic response to change over time is a "variable chasing a variable not a constant"
Jackson 1997

Lessons from History for AM

What is: Native Species, Native Range, Rare/Common?

Species migrate by colonizing beyond range margins or habitats, and dying at others

Millar 1998, Millar & Brubaker 2006

BC Ministry of Forests

Our conservation philosophies sometimes hinder capacity for species to move adaptively

What Does and Doesn't Define Ecological Sustainbility?

Sierra Nevada, CA

Distinct Bioregion? Yes √
Diversity of Plant Species? Yes √
Lack of Species Extinction? Yes √

Stable Species Ranges and Distributions? No
Stable Species Abundances? No
Stable Community Composition & Diversity? No
Stable Disturbance Regimes? No

Millar & Woolfenden 1999

What Targets are Defensible for Restoration?

Pre-disturbance (HRV) conditions rarely appropriate

What does it mean to be invasive?

Many historic invaders are current natives

The "Red Queen" Rules:

Species/populations often lag behind changing climates


Photo: Malene Thyssen,
http://commons.wikimedia.org/wiki/User:Malene

Vegetatio 67: 75–91, 1986

Is vegetation in equilibrium with climate? How to interpret late-Quaternary pollen data

Thompson Webb III*
Department of Geological Sciences, Brown University, Providence, RI 02912-1846, USA

Disturbance Historically:

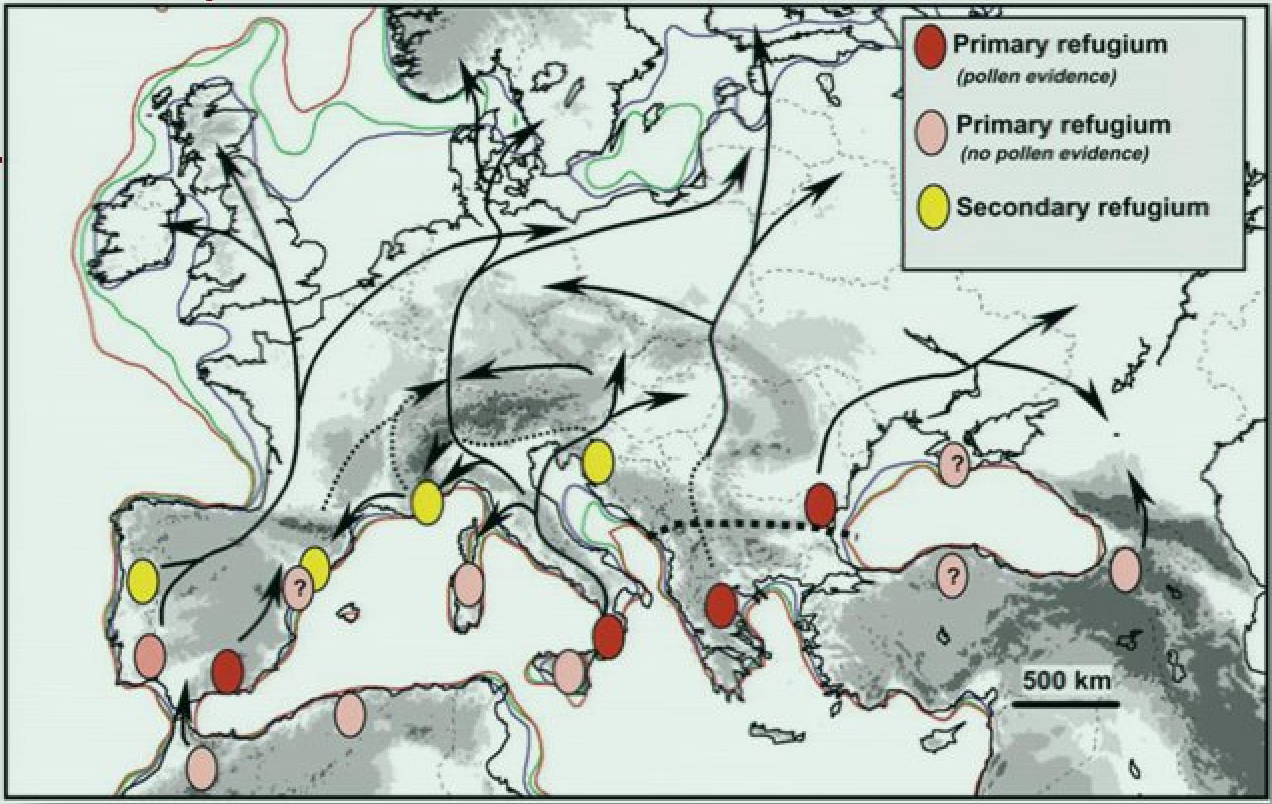
A time to catch up with climate change

Refugia have played critical roles in species persistence historically

Refugia
Areas within or beyond extant native ranges where species persisted during periods of climatic change, climatic variability, and climatic extremes

Glacial Oak Refugia & Dispersal Corridors, Petit et al. 2002

"The advantage of long holidays"



In Sum (Part 1)

*Change has been constant through history, but that doesn't mean "anything goes" for management

Best practices strive to:

*Work with natural capacities of species to adapt to change

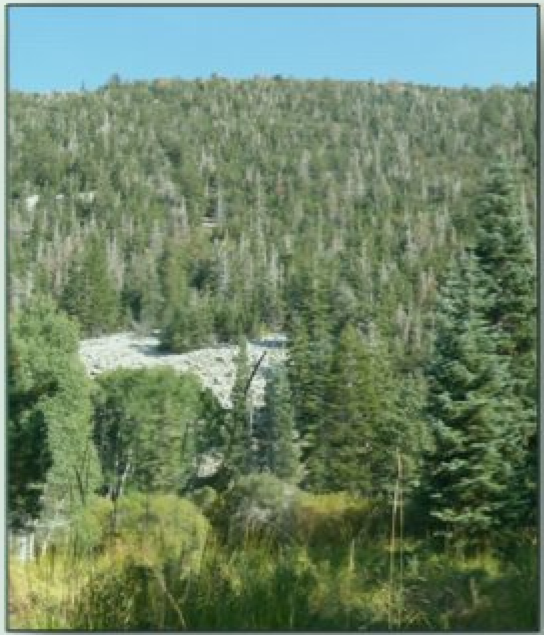
*Assist by removing barriers that impede natural adaptation

PART 2: Assisted Migration in Climate Adaptation

When and Where to Employ It?

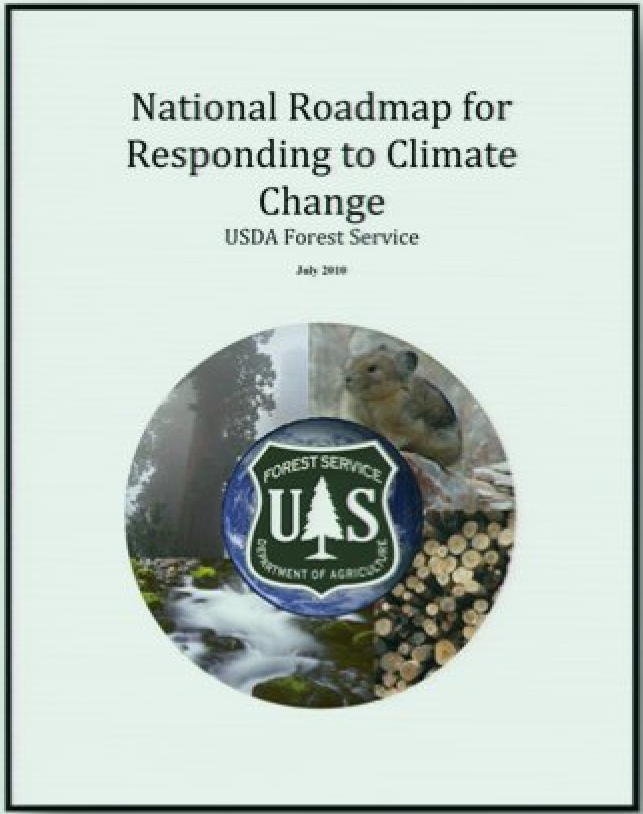
Management Decisions

- Do Nothing: No Advance Action
- React after Disturbance or Extreme Events
- Be Proactive: Act in Advance



Institutional Goals Influence Decisions about AM

Ecosystem Services Sustained Goods & Services



Ecosystem Management "Species Rescue", Sustained Ecosystems

Incorporating Assisted Migration

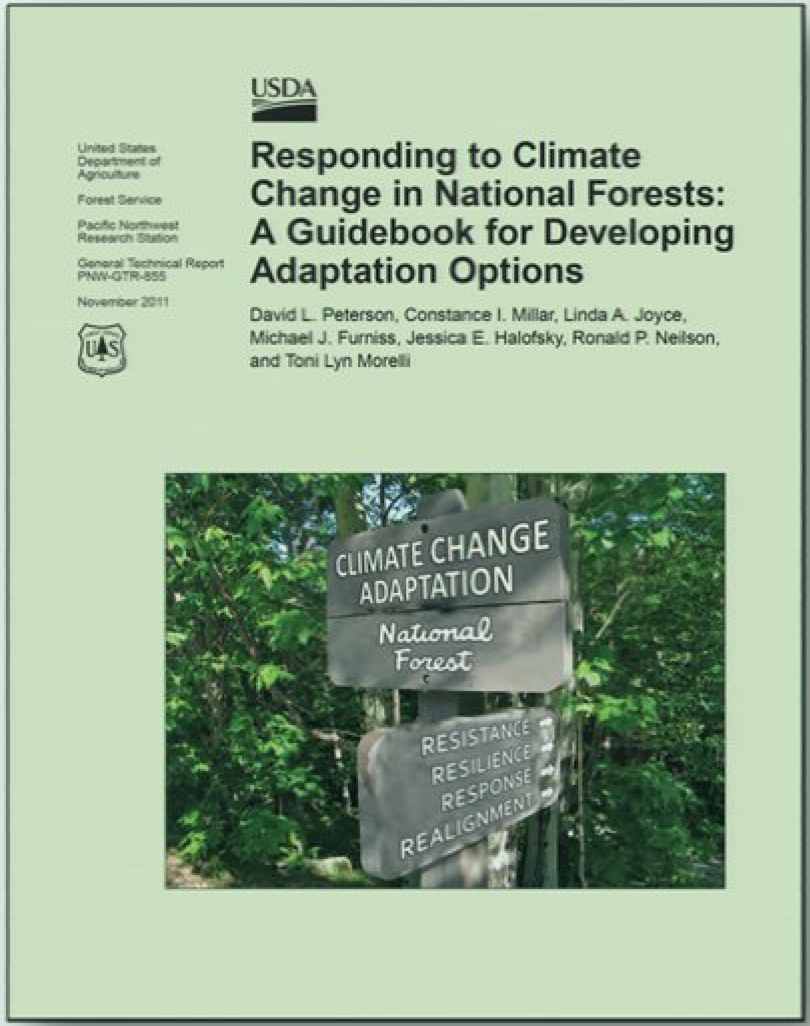
Four Strategic Steps in Climate Adaptation

Step 1: Assess Vulnerabilities

Step 2: Set Priorities

Step 3: Select Options, Strategies, and Tactics

Step 4: Monitor and Adjust



General Principles in AM Decision-Making

WHEN? Know Your Scale

1. Short Term (<10 yrs, unit scale)

   Project Scale:
   - Do No Harm
   - Don't Fix What Ain't Broken

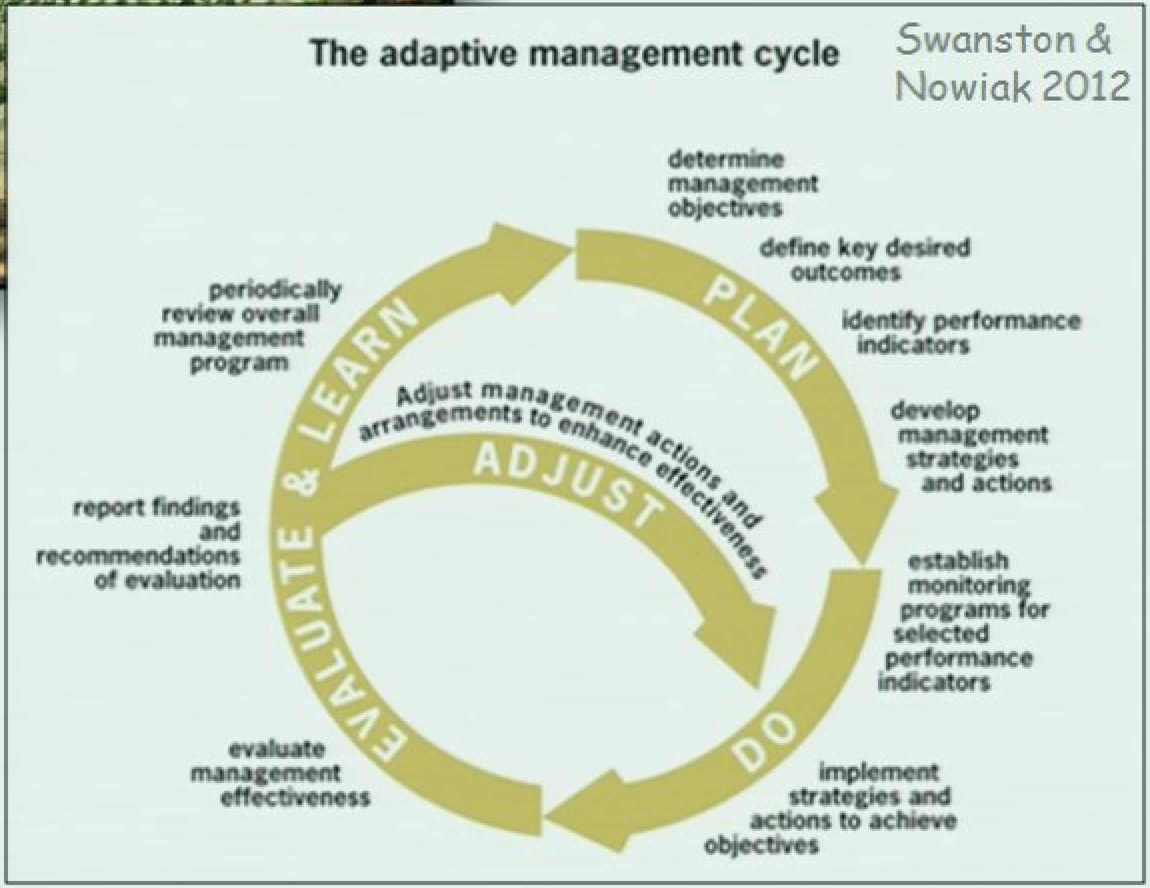
2. Longer Term (>10 yrs, landscape scale)

   Planning Scale:
   - Anticipate Surprises; Ease Transitions
   - Hedge Bets; Assess Risk vs Urgency

Urgency and Risk

How much to invest in assessment?

Experimental Plantations
and/or
Adaptive Management



General Principles in AM Decision-Making

WHERE? Location Matters

1. Source Location (Donor)

- environmental context
- genetic context
- health, history

Pinus ponderosa

2. Destination (Recipient)

- environmental context
- impacts to target species
  - impacts to receiving ecosystem

Adaptation Options

* Increase *Resistance*
* Promote *Resilience*
* Assist Adaptive *Responses*
* *Realign* Degraded or At-Risk Systems

Millar et al. 2007

1. Increase *Resistance* to Change

Defend highest-value resources against change

...heavily armored stream crossings & oversized culverts

Usually short-term, stop gap measures

...heroic fire breaks

***AM: Opportunities less likely**

2. Promote *Resilience* to Change

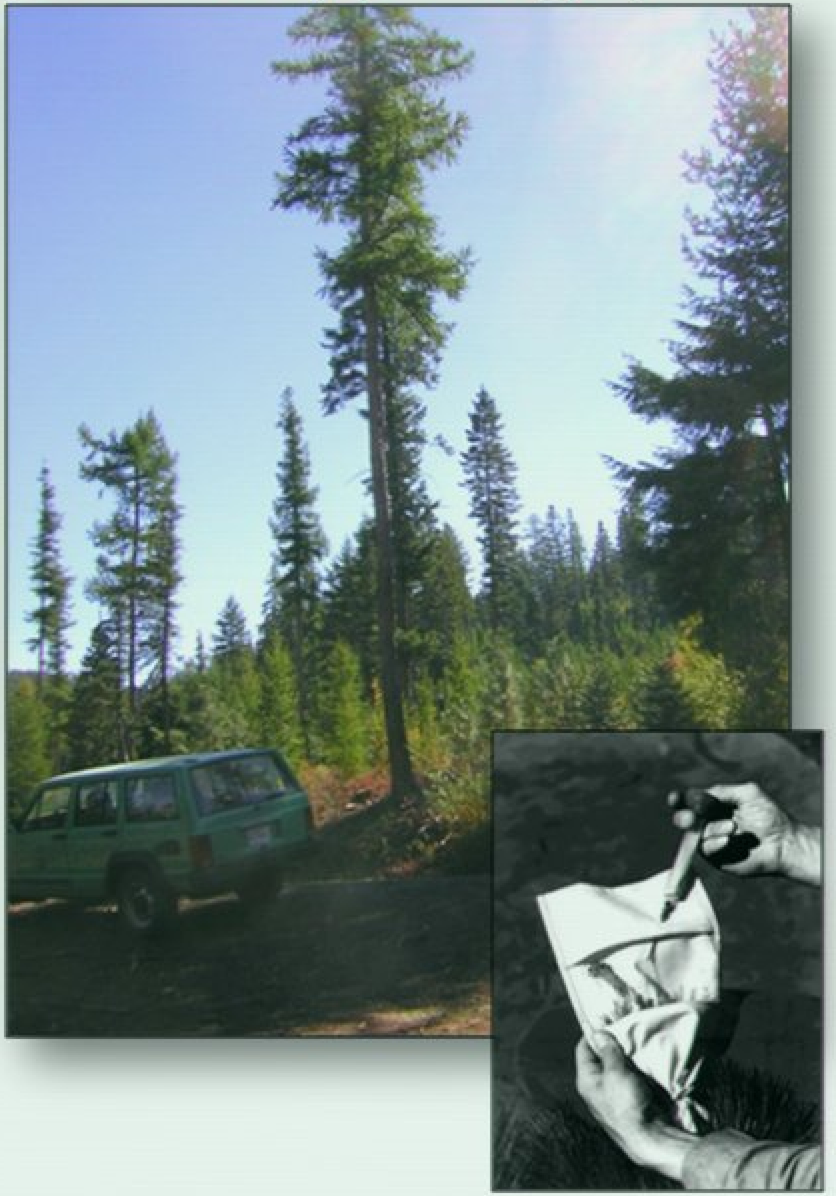
Improve the capacity of ecosystems to return to prior conditions after disturbance

Examples

- Thin Forest Stands
- Prescribe Fires
- Stock Seed Banks
- Increase Rare Species Population Targets

Improve the capacity of a system to absorb external challenges without change in state

*AM: Use disturbance, e.g., fire or harvest, as place & time for assisted genetic-migration projects (within spp range)



Increase stand-level diversity:

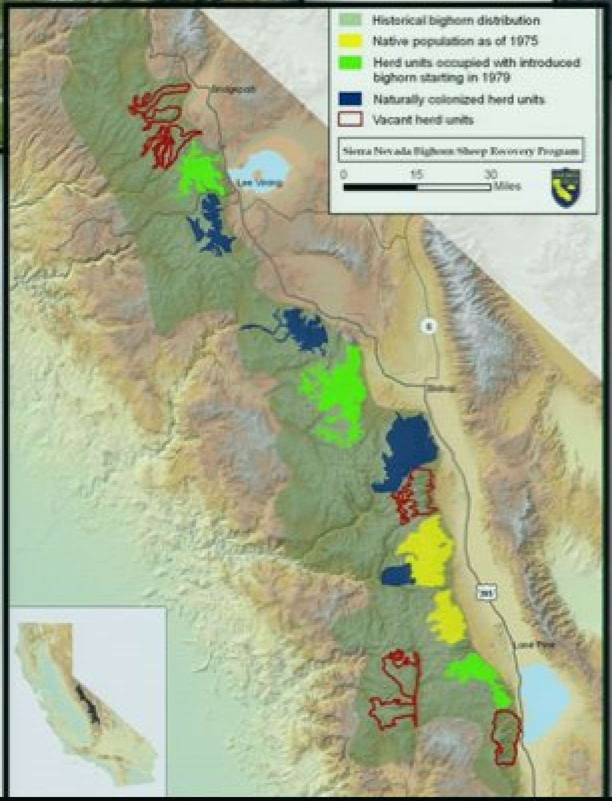
a) Targeted donor provenance

b) Deliberate mix of provenances (mix of seed zones or intentional hybridizations)

*AM: Assess, protect and augment refugia, natural or ex-situ

...riparian zones

..endangered species



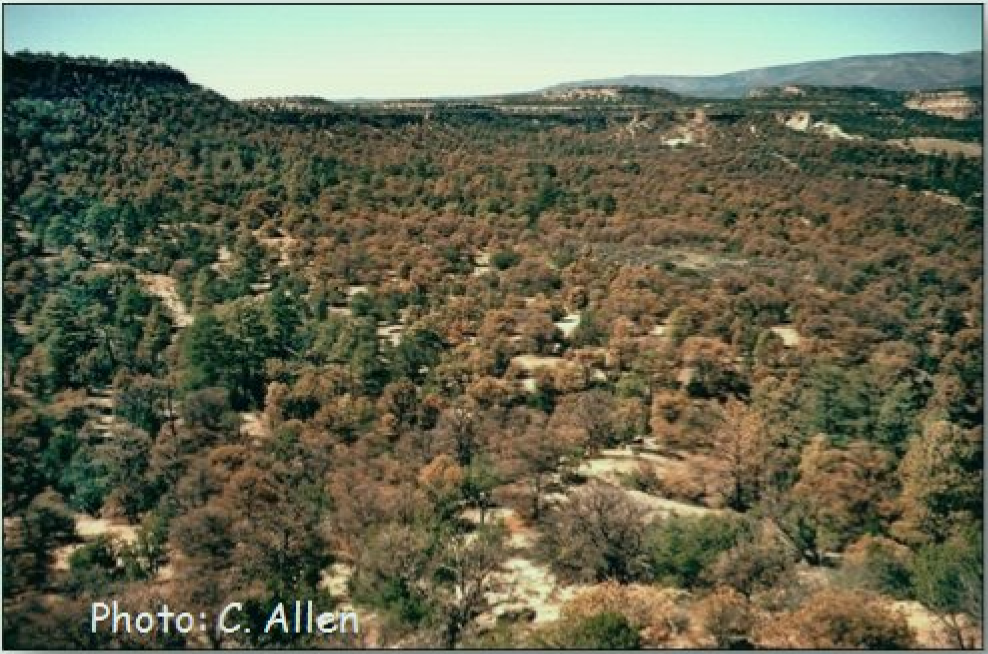
...arboreta, plantations, seed banks

Within or beyond spp range

3. Assist Adaptive *Responses*

Assist transitions to new conditions or locations

Ecological conversions are occurring already



Forest to Grassland
Colorado plateau, *Pinus edulis*
Drought & bark beetles

Grassland to Forest
Great Basin, *Pinus monophylla*
Warming & fire suppression

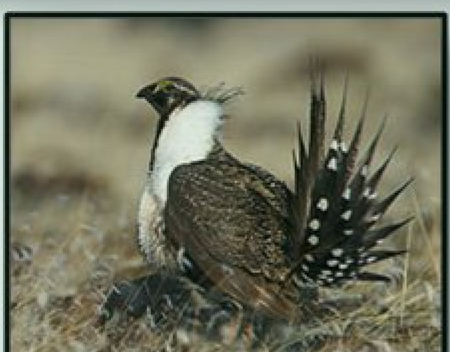
*AM: Use disturbance (natural or managed) to introduce species beyond their range limits: offsite; margins; disjunct

...new species mixes

Brewer Spruce

***AM:** Ease changes that are ongoing (don't resist the tide)

Pinyon/Juniper and Sage Steppe



***AM:** Experiment with restoring historic diversity from similar climatic- and ecologic niches

Giant sequoia, currently 75 small, disjunct groves in the W Sierra Nevada mixed-conifer belt; widespread >4,000 yrs ago

*AM: Consider very different options for source of germplasm on novel sites

Example #1: Silver fir in Denmark; provenance studies

Current distribution

...a story told by Palle Madsen, Univ Copenhagen, 1/2013

Glacial refugia for silver fir were along Mediterranean Sea

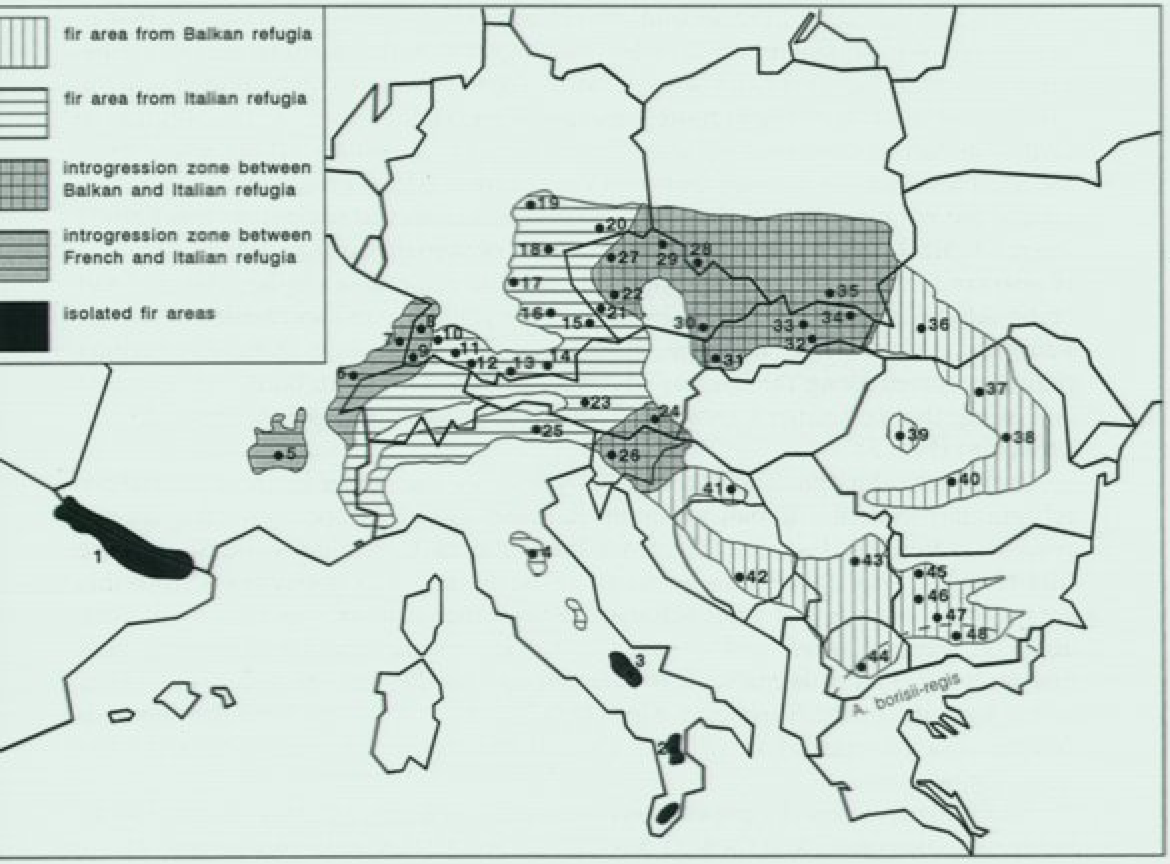


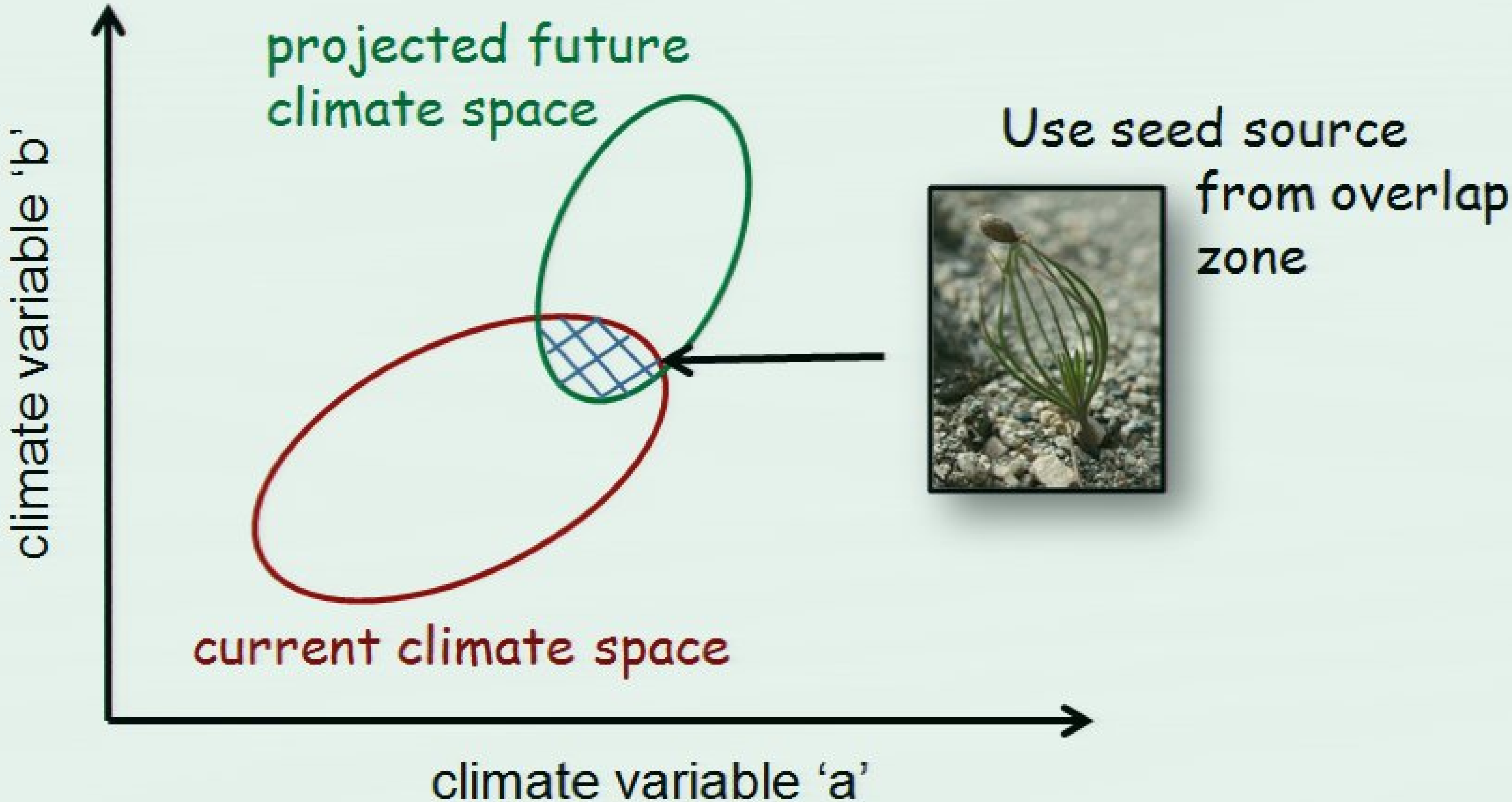
Fig. 3. Schematic illustration of the natural range of silver fir subdivided into different areas which result from glacial refugia and their putative introgression zones; geographic locations of sample sites (no.) correspond to those in Table 2 and Figs. 1 and 2

Konnert & Bergmann 1994

Vendramin et al. 1994

Assisted Migration

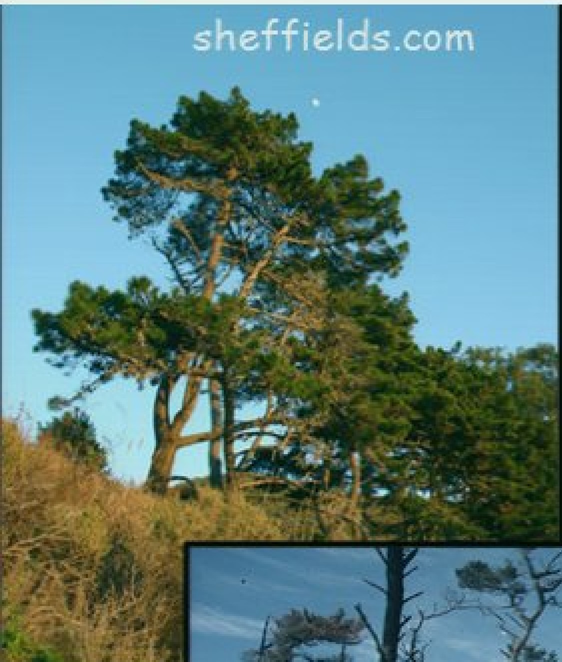
Forging new ground in British Columbia



…a story told by Phil Burton, Univ North British Columbia, 1/2013

4. *Realign* Systems to Current & Future Dynamics

An option when resources are severely degraded or at risk in current range



Monterey Pine

Pinus radiata:
Quaternary (red) and Extant (yellow) Populations

Millar 1998, Millar & Brubaker 2006

A very few words on law, regulations, and policy

Dissonance with Natural Resource Law:

1. Inconsistent with natural resource preservation mandates
   - E.g., Endangered Species Act, National Forest Management Act, Wilderness Act
   - E.g., ecosystem sustainability precepts, control of invasives, forest health initiatives, HRV practices
2. Incongruous with existing decentralized management

   "...natural resource law in the United States fails to provide a reasonably coherent framework for managing efforts like assisted migration for adapting natural resources to the effects of climate change…"

   I.e., current laws are fragmented by resource, agency, impact

***SEE*: Comacho, AE. 2010. Assisted Migration: Redefining Nature and Natural Resource Law Under Climate Change Legal Studies Research Paper Series No. 2009-37 UC Irvine**

From the US Forest Service perspective…

"Assisted migration should only be done operationally:

-when seed movement studies have been done for the specific species in question, or

-when forest health, regeneration, or productivity monitoring data indicate there are climate-change-related problems."

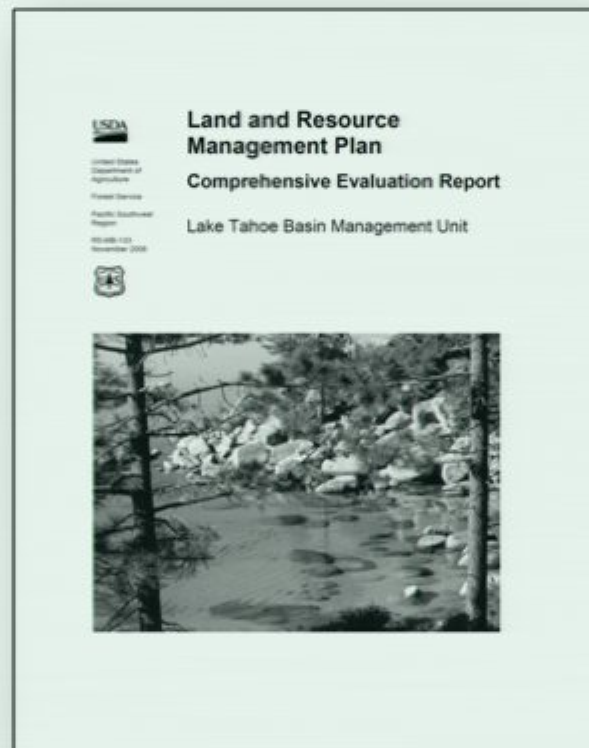
White pine germplasm & species trials

Blister rust in sugar pine

Johnson, R. et al. 2012. Policy and strategy considerations for assisted migration on USDA Forest Service lands. White paper

USFS General Guidelines

- Consider local species/seed sources that have worked in the past;
- If reforestation problems exist, expand local seed to include germplasm better matched to new conditions;
- Emphasize genetic diversity, multiple species, and multiple seed sources;
- Encourage large populations with high connectivity;
- Use a 10-20 yr planning horizon to minimize risks at seedling/sapling stage;
- Take high-risk actions over small areas on experimental basis;
- Take low-risk actions over larger areas.


Land and Resource Management Plan

Comprehensive Evaluation Report

Lake Tahoe Basin Management Unit

In Sum (Part 2)

-Mimic natural capacities of species to adapt
-Ease anticipated and inevitable transitions
-Assist species to navigate anthropogenic barriers

When & Where to Employ AM depends on:

-Management Goals
-Vulnerabilities
-Priorities
-Time Horizons for Planning
-Spatial Scales for Planning
-Prior Knowledge (genetics/spp)
-Risks & Urgency

Assisted migration can be an important practice in the climate adaptation toolkit for both environmental protection and ecosystem services objectives

For more information, please visit the US Forest Service Reforestation, Nurseries & Genetics Resources website at **http://rngr.net**