

# Restoration in the Context of Global Change

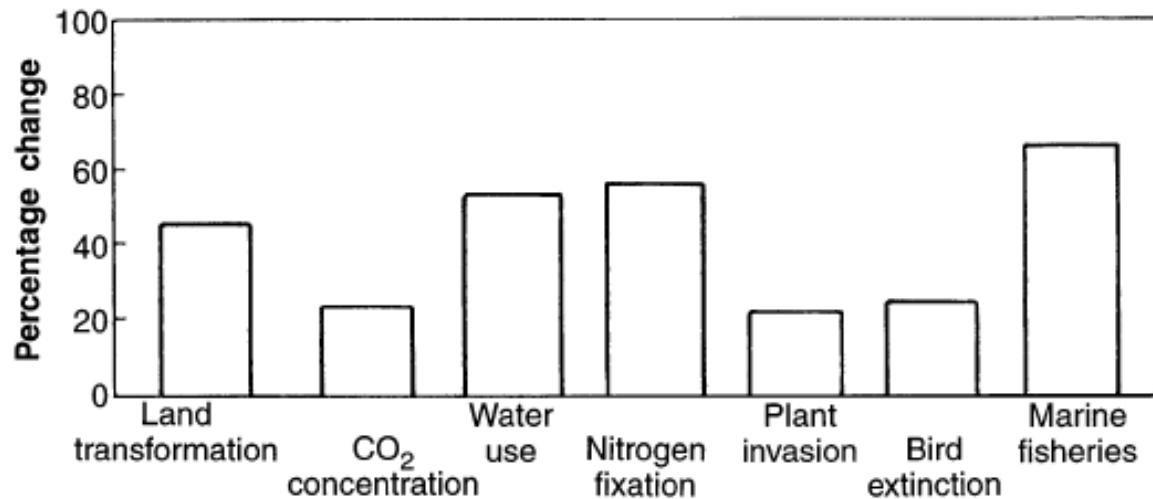
- Objectives
  - Introduction to global change biology
    - Land transformations
    - Alterations of biodiversity
    - Alterations of global biogeochemical cycles
      - N, H<sub>2</sub>O, C
    - Climate Change
  - Implications of global change biology for restoration ecology / ecological restoration

# Restoration in the Context of Global Change

- The “Anthropocene” Era
  - Humans dominate the Earth and have led to substantial changes in the structure and function of terrestrial, marine, and freshwater ecosystems

# Restoration in the Context of Global Change

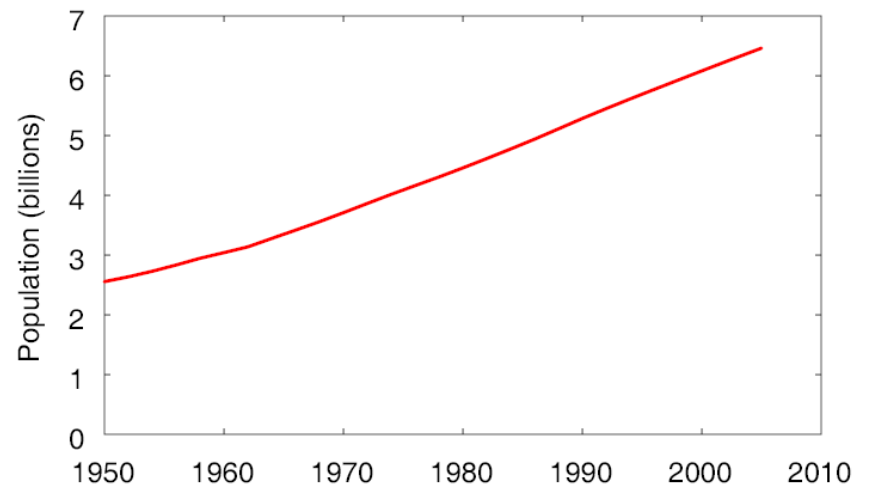
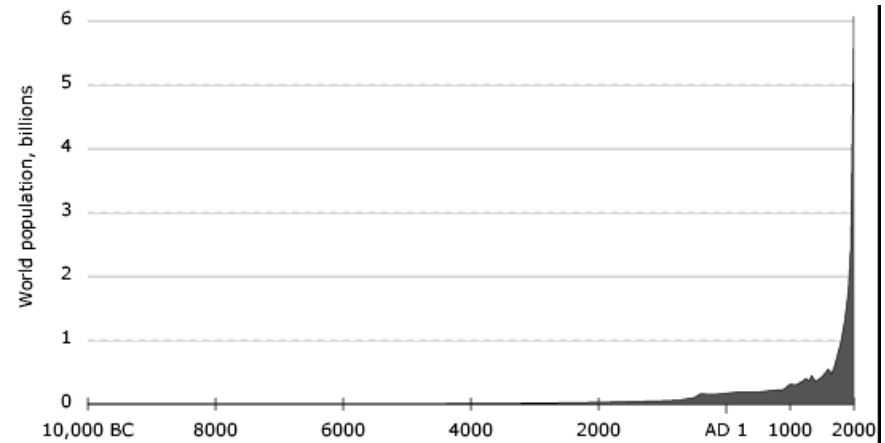
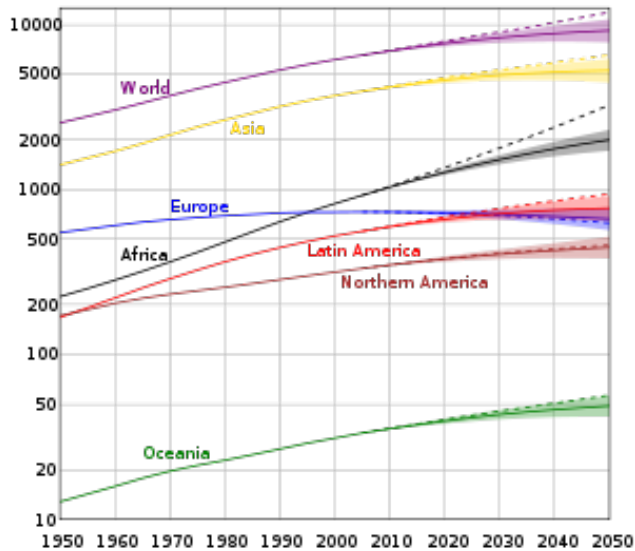
- The “Anthropocene” Era



Vitousek *et al.* 1997

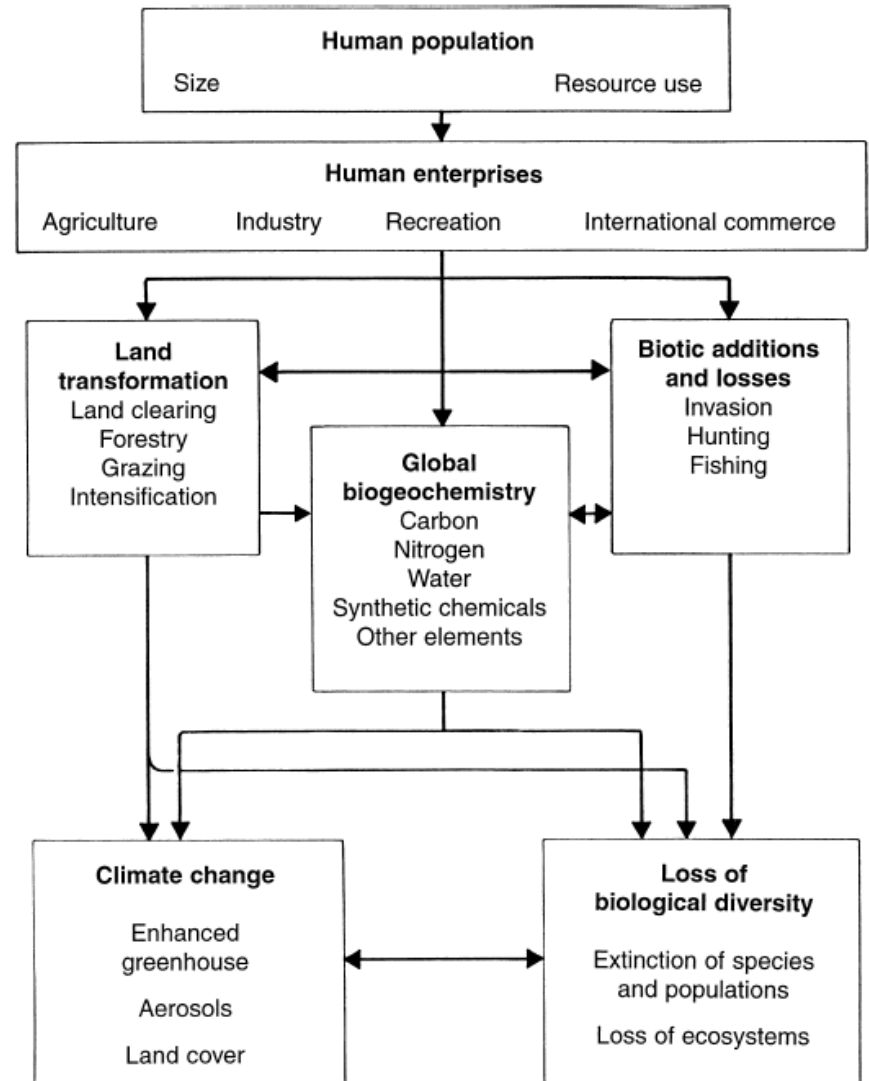
# Restoration in the Context of Global Change

- In 2005-2006, the human population grew by 203,800 people **every day**



# Restoration in the Context of Global Change

- Direct and indirect influence of humans on the Earth system



Vitousek *et al.* 1997

# Restoration in the Context of Global Change

- Land transformations (39-50% of Earth's surface)
  - Row crop agriculture and urbanization (10-15%)
  - Conversion to pastureland (6-8%)
  - Grazing by domestic animals and extraction of wood products (25%???)



# Restoration in the Context of Global Change

- Implications of land transformations for restoration
  - Habitat loss and fragmentation
    - 1° driving force behind loss of biodiversity
    - Alters genetic diversity & population dynamics
    - Alters local and regional climate
    - Increases atmospheric CO<sub>2</sub> concentrations → global climate change
    - Pollutes air and water
    - Reduces fitness and stability at every level of the ecological hierarchy

# Restoration in the Context of Global Change

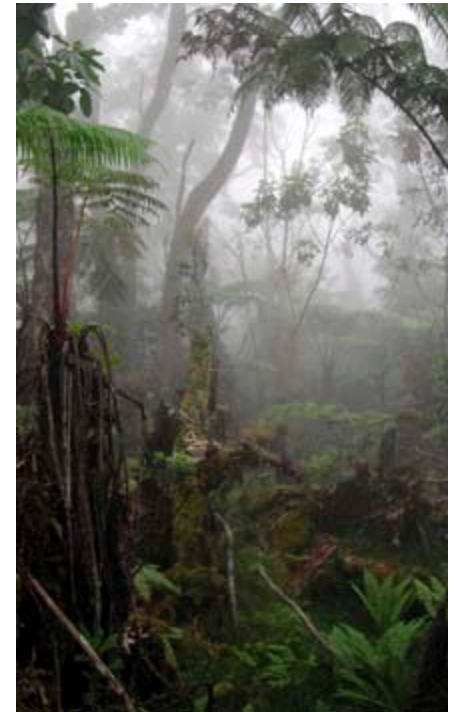
- Alteration of biodiversity - Extinctions



from left to right

**Kauai O'O Extinct, Kauai Akialoa Extinct, O'u Extinct,  
Kauai Nukupu'u Extinct, Puaiohi less than 200 remain, Kamao Extinct**

[www.ahunaturetours.com](http://www.ahunaturetours.com)



# Restoration in the Context of Global Change

- Alteration of biodiversity – Additions (invasive species)

## Hawaii

*Psidium cattleianum*



*Pennisetum setaceum*



*Puccinia rust*



# Restoration in the Context of Global Change

- Implications of alterations in biodiversity for restoration
  - Alters the regional species pool
    - Extinctions
      - Loss of pollinators, seed dispersers, etc.
      - Loss of keystone species
      - Alterations in structure & function of ecological systems
    - Invasions
      - 2<sup>nd</sup> most important causal agent of extinctions
      - Changes in species biodiversity
      - Alterations in structure & function of ecological systems

# Restoration in the Context of Global Change

- Alteration of biogeochemical cycles - Nitrogen

**N fixation**



← Natural →

**N deposition**



vs.

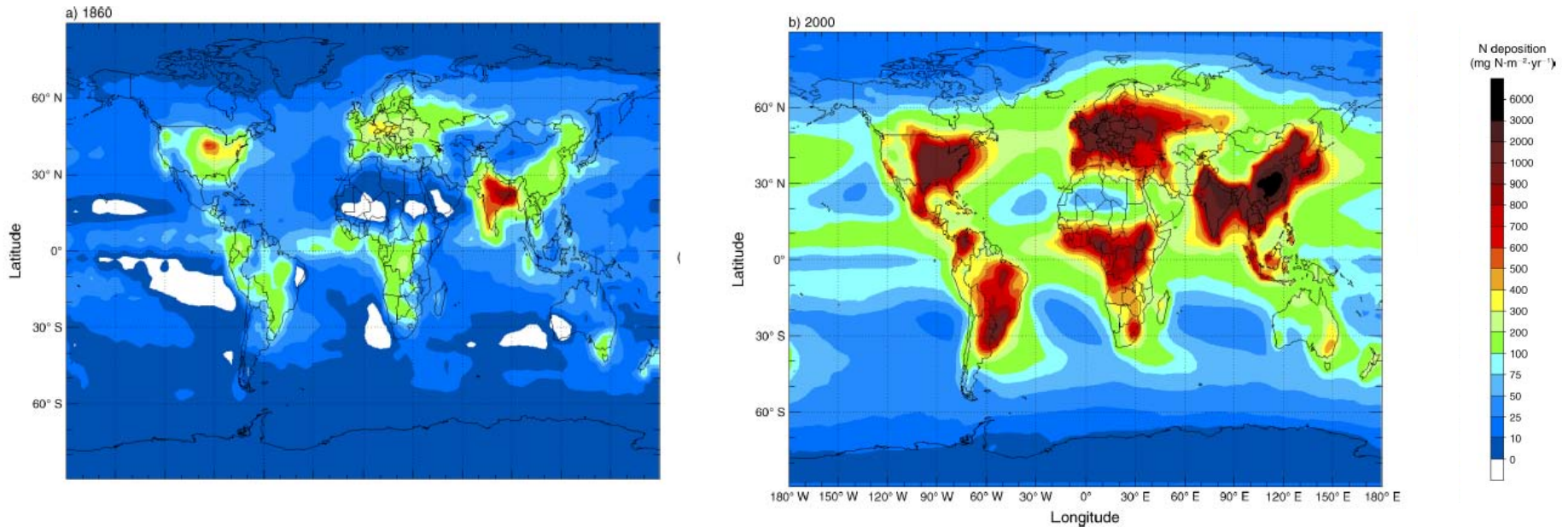


← Anthropogenic →



# Restoration in the Context of Global Change

- Alteration of biogeochemical cycles - Nitrogen



# Restoration in the Context of Global Change

- Implications of altered N cycling for restoration
  - Alters cycling and availability of N in ecological systems
    - Changes competitive interactions
  - Leads to N saturation and toxicity
  - Alters coupled biogeochemical cycles
    - Calcium deficiencies
    - Changes in C source/sink dynamics
  - Potent greenhouse gases → global climate change

# Restoration in the Context of Global Change

- Alteration of biogeochemical cycles - Water

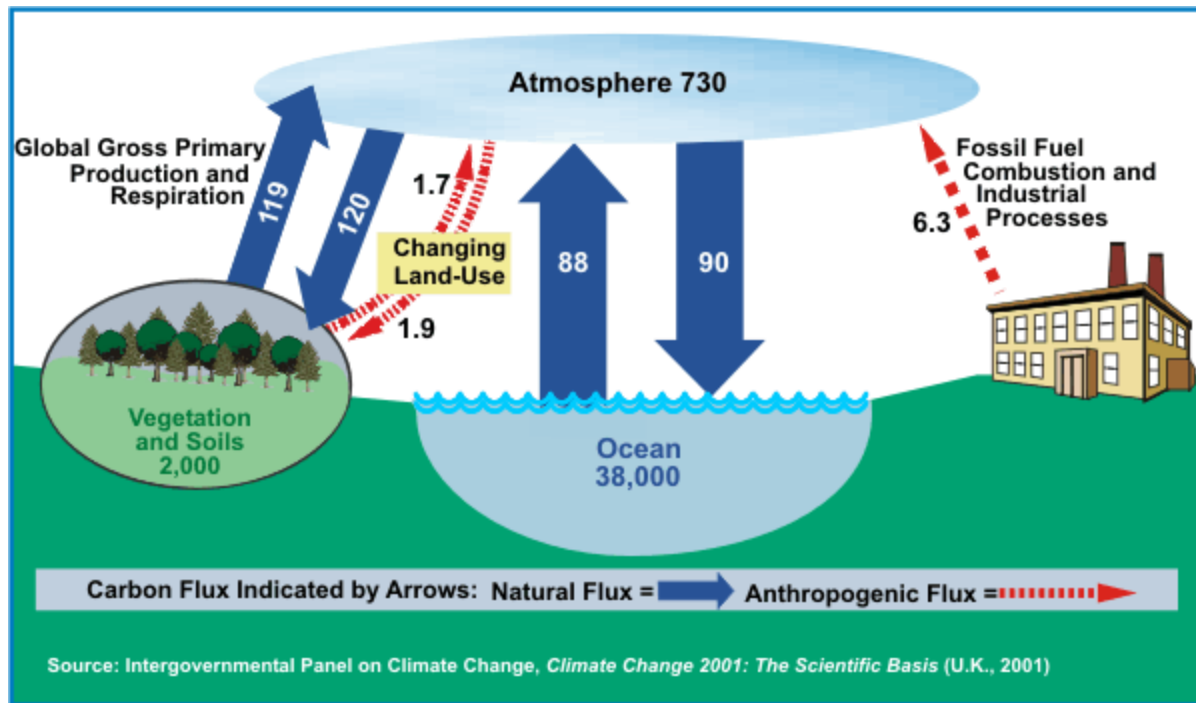


# Restoration in the Context of Global Change

- Implications of altered H<sub>2</sub>O cycling for restoration
  - Alters availability and use of H<sub>2</sub>O in ecological systems
    - Changes competitive interactions
  - Alters precipitation regimes at local and regional scales
  - H<sub>2</sub>O is the major greenhouse gas → global climate change

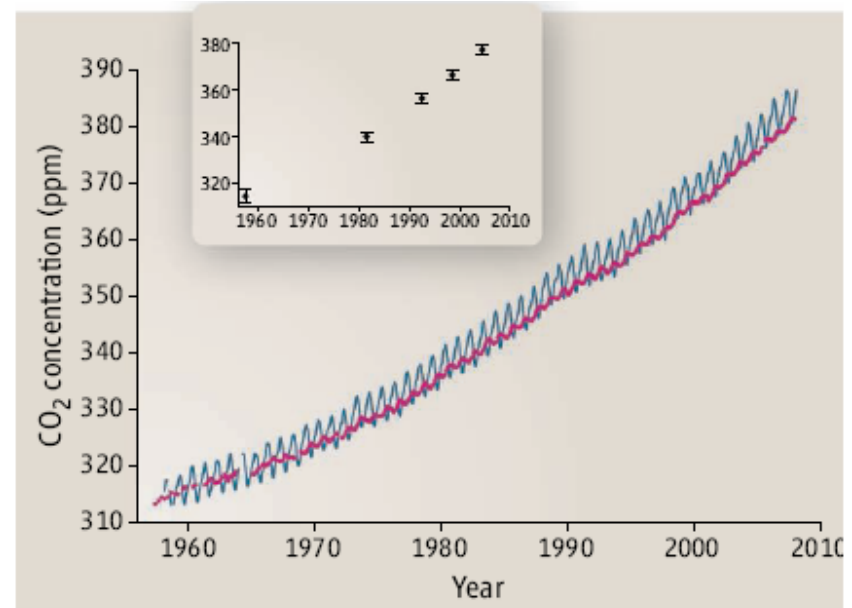
# Restoration in the Context of Global Change

- Alteration of biogeochemical cycles - Carbon



# Restoration in the Context of Global Change

- Increased atmospheric CO<sub>2</sub> concentrations
- Globally, result of:
  - Fossil fuel emissions (~2/3)
  - Land Transformations (~1/3)



# Restoration in the Context of Global Change

- Implications of altered C cycling for restoration
  - Global Climate Change alters:
    - Species distributions (regional and local species pool)
      - Changes competitive interactions
    - Ecosystem structure and function

# Restoration in the Context of Global Change

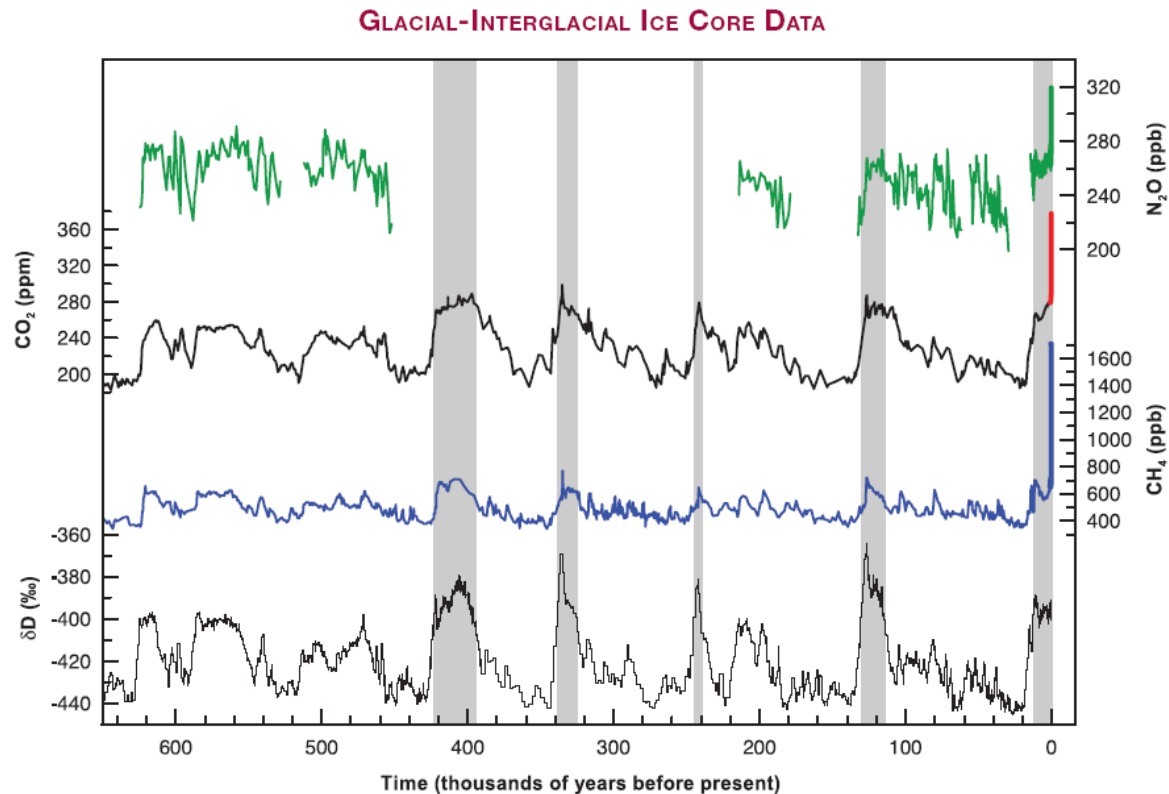
- Weather vs. climate
- Is the global climate changing and, if so, is it the result of human activities?
  - Only need to believe 2 things
    - 1) Atmospheric constituents (i.e., greenhouse gases) trap outgoing longwave radiation, thereby warming the atmosphere
    - 2) Human activities are increasing the concentrations of greenhouse gases in the atmosphere
  - There is no argument about #s 1 and 2
  - The questions we should be asking are:
    - How much will the climate change?
    - What will the impacts of that change be for the goods and services that ecosystems provide humankind?

# Restoration in the Context of Global Change

- How do we know that climate is changing now, and that it is a result of human activities?

- Ice cores

- Strong correlation between greenhouse gas conc. and temp.
- Higher conc. of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O than anytime in the past 650,000 years
- Biosphere has taken up ~50% of CO<sub>2</sub> emissions



# Restoration in the Context of Global Change

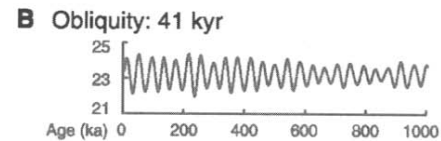
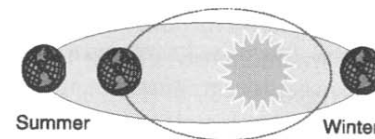
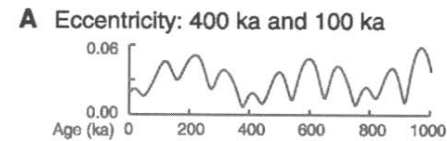
- How do we know that climate is changing now, and that it is a result of human activities?

“Milankovitch (orbital) cycles”

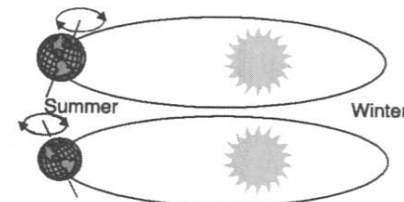
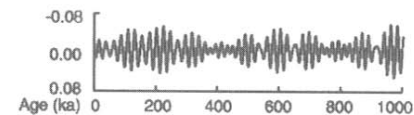
A. ° of ellipticity of orbit (100,000 & 400,000 years)

B. Change in tilt of Earth’s axis; obliquity or “wobbling” (41,000 yrs)

C. Change in time of year of perihelion (23,000 yrs)

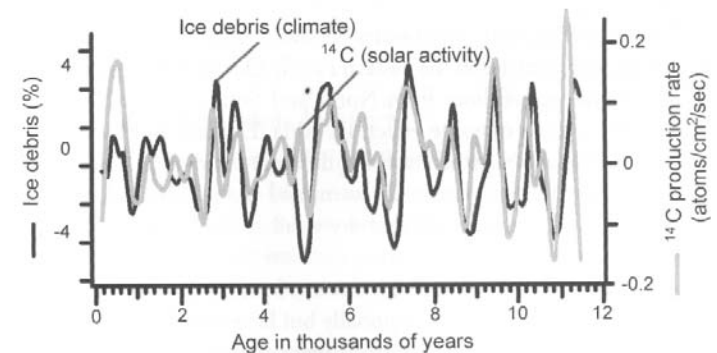


**C Axial precession: 23 kyr**

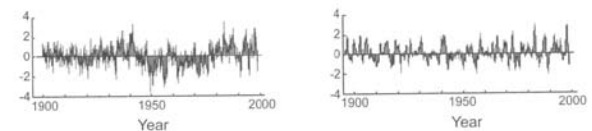
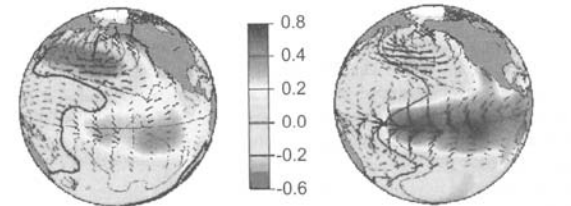


# Restoration in the Context of Global Change

- How do we know that climate is changing now, and that it is a result of human activities?
- Century to millennial scale cycles
  - Bond Cycles
- Interannual to decadal-scale cycles
  - ENSO (interannual)
  - PDO (multidecadal)

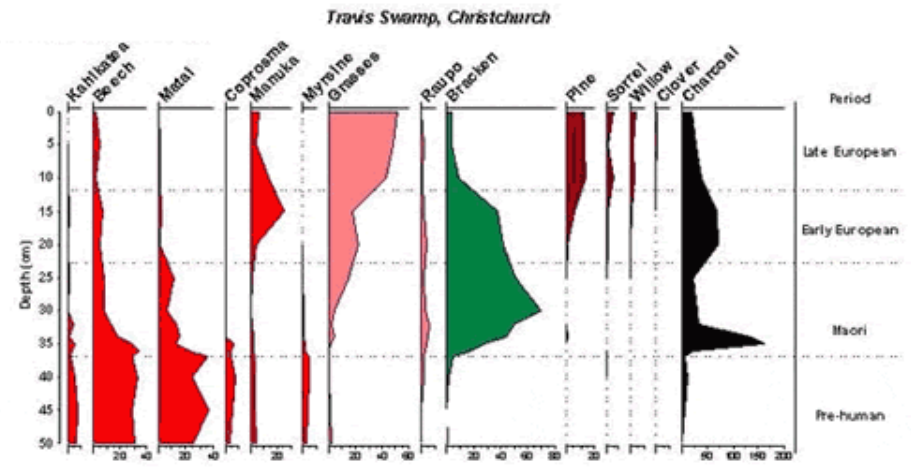
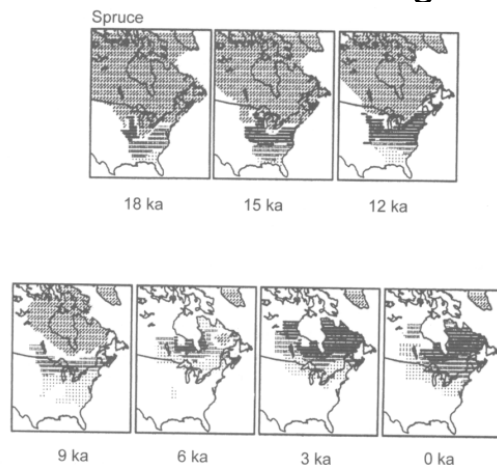


Pacific Decadal Oscillation (PDO)    El Niño Southern Oscillation (ENSO)



# Restoration in the Context of Global Change

- Climate has always been variable in the past, so why should we care if it is changing now?
- Ecological systems respond to climate change
  - Climate has fluctuated for at least 2.5 million years (likely 20 million years)
    - Complete species turnover
    - Recurring patterns of similar groups of species over time
    - Species respond individually
    - No-analog communities

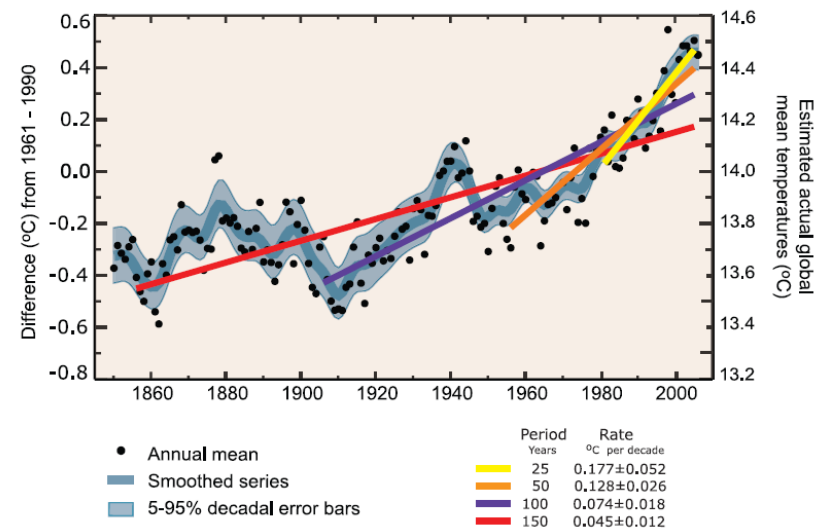
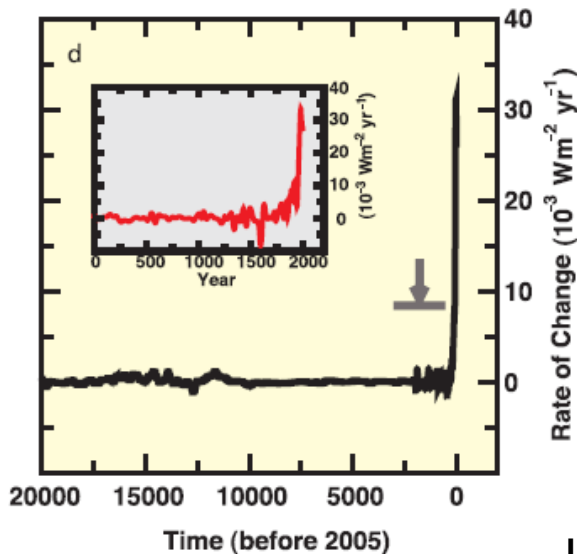


# Restoration in the Context of Global Change

- Climate has always been variable in the past, so why should we care if it is changing now?
- Climate oscillated between warm/cold & wet/dry periods for at least 2.5 million years (likely 20 million) at multiple & nested temporal scales
  - Interannual, decadal, century and millennial scales (relatively predictable)
- Climate transitions occur abruptly
- Vegetation responds to climate change at all temporal scales
  - Evolutionary and ecological forcing on ecological systems to adapt to fluctuating climate and rapid transitions
  - Plant communities are transient assemblages of species, where each species responds to climate change individually through time and space
- Contemporary, anthropogenic climate change can only be understood within the context of natural climate variability

# Restoration in the Context of Global Change

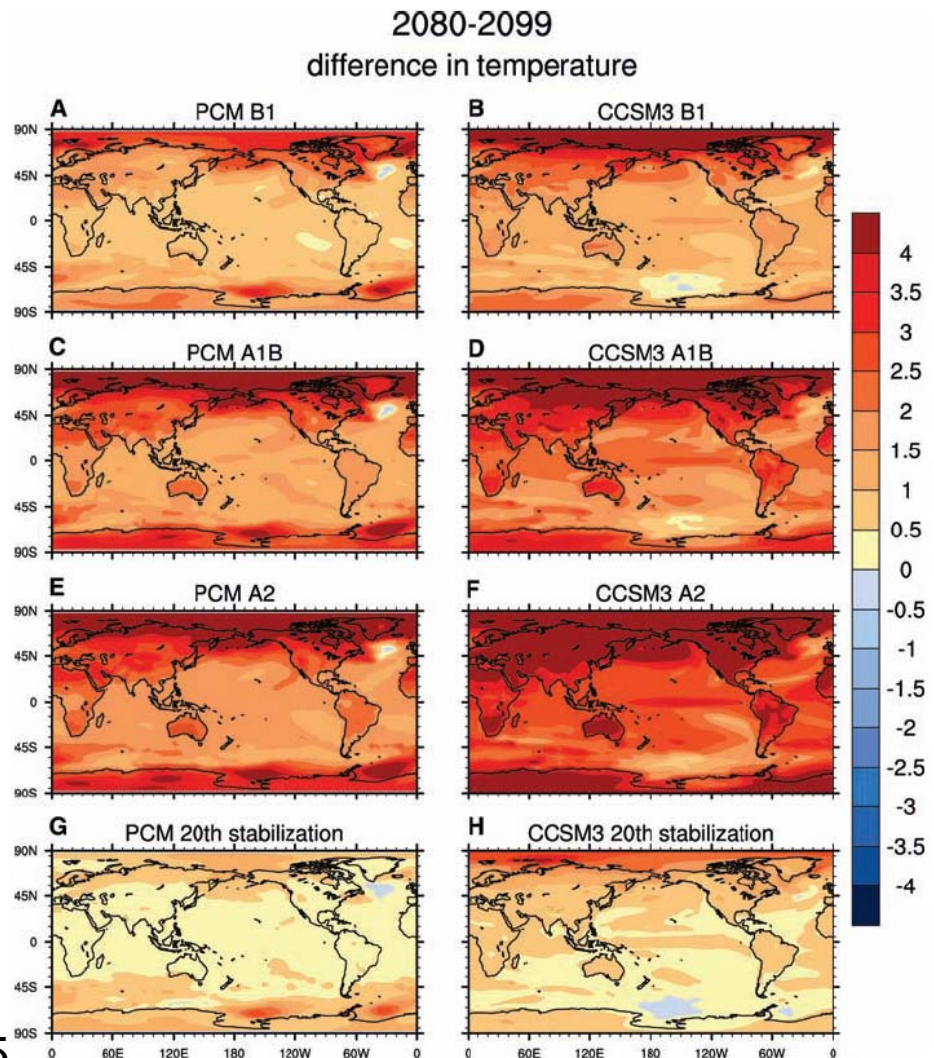
- Climate has always been variable in the past, so why should we care if it is changing now?
  - Rate of change far exceeds that from anytime in the past
    - Prior to 1750, CO<sub>2</sub> increased by 20 ppm over 8,000 years
    - Since 1750, CO<sub>2</sub> has increased by >100 ppm



IPCC 2007

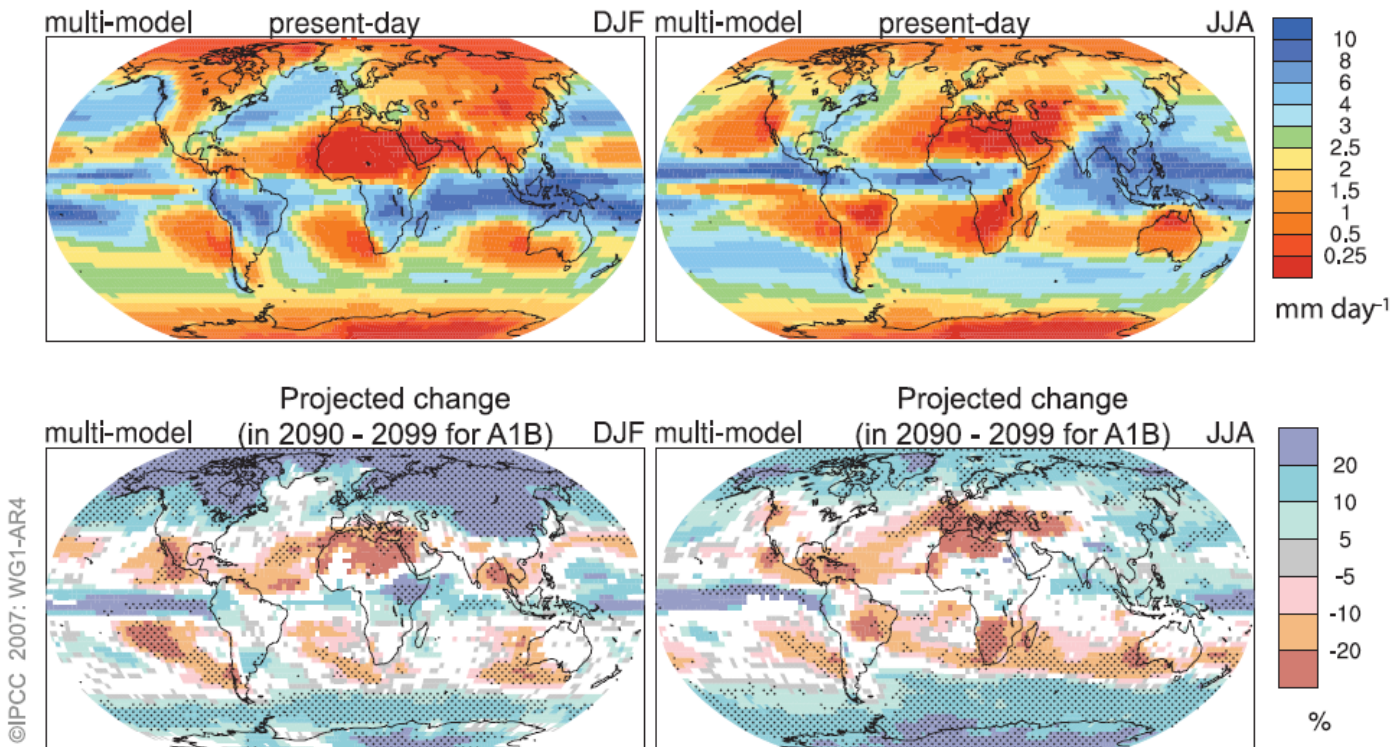
# Restoration in the Context of Global Change

- Projected temperature change
  - Uneven distribution of temperature increase across the globe
- What's the big deal about a  $\sim 5^{\circ}\text{C}$  global increase?
  - Difference between glacial & interglacial is  $\sim 10\text{-}20^{\circ}\text{C}$  globally



# Restoration in the Context of Global Change

- Projected change in precipitation ( $\text{mm day}^{-1}$ )



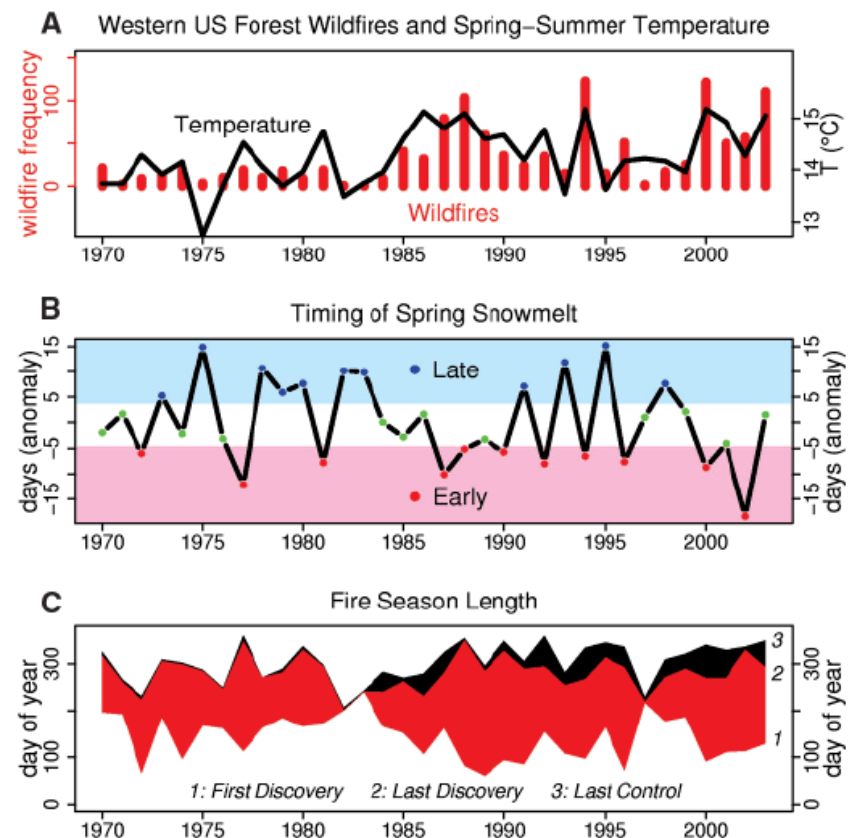
# Restoration in the Context of Global Change

- Projected changes in the occurrence and intensity of natural disturbances



# Restoration in the Context of Global Change

- Climate change will impact disturbance regimes
  - Positive feedback / forcing:
  - Increased temps → earlier spring snowmelt → increased moisture deficit → larger and more frequent fires → increased greenhouse gas → increased temperature → etc.



# Restoration in the Context of Global Change

- Implications of altered climate for restoration
  - Climate, more than anything else, controls the distribution of species across the planet
    - “...*natural climate system as a pervasive force of ecological change*”
    - Paleoecological studies indicate that species have moved considerably as climate has changed at all temporal scales
      - Species act individualistically (→ no-analog communities)
  - More frequent “extreme” events
  - Changes in disturbance regimes
    - More frequent and severe fires, hurricanes, etc.
    - HRV?

# Restoration in the Context of Global Change

- Implications of altered climate for restoration
  - “...*climate is a macrodisturbance element, or the background stage of change on which evolutionary and successional dynamics play out*”
  - Contemporary climate change completely changes the playing field for reference endpoints/trajectories
    - Ecological & evolutionary adaptation to prevailing conditions, and/or those that existed in the past
      - Future conditions may differ greatly, and current climate change is occurring at unprecedented rates
        - Capacity of ecological systems to adapt?
          - Need for assisted migrations?
        - Restore static historical systems or realign systems to current and future anticipated conditions?