Restoration in the Context of Global Change

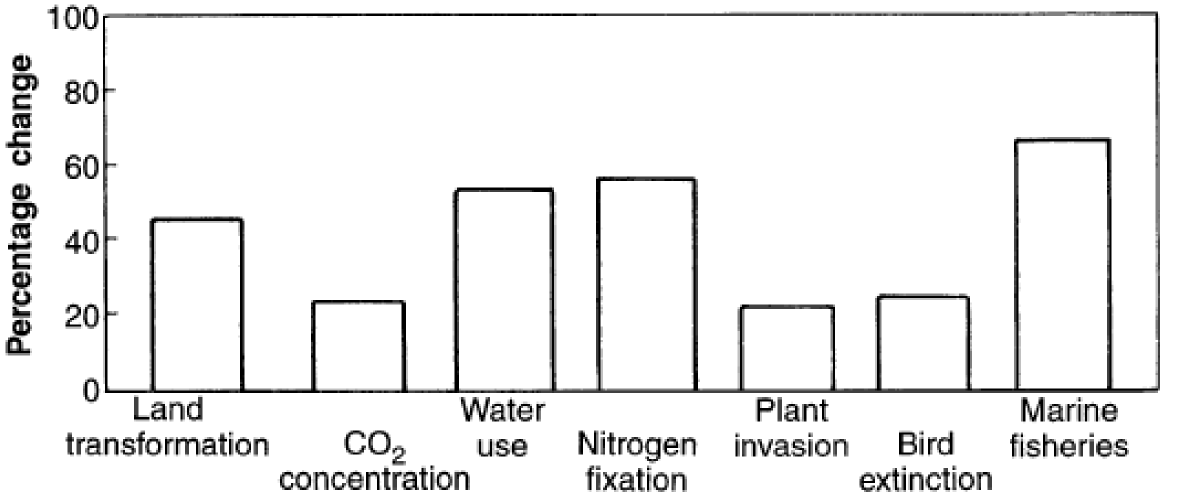
- Objectives
  - Introduction to global change biology
    - Land transformations
    - Alterations of biodiversity
      - Extinctions (-) and Invasions (+)
    - Alterations of global biogeochemical cycles
      - N, H_2O, C
    - Climate Change
  - Implications of global change biology for restoration ecology & ecological restoration

Restoration in the Context of Global Change

- The “Anthropocene” Epoch
  - Humans dominate the Earth and have led to substantial changes in the structure and function of terrestrial, marine, and freshwater ecosystems
    - Term coined in 2000 by scientists Paul Crutzen and Eugene Stoermer
    - Influence of human behavior on Earth in recent centuries is so significant as to constitute a new geological era
    - Info at http://www.anthropocene.info/

Restoration in the Context of Global Change

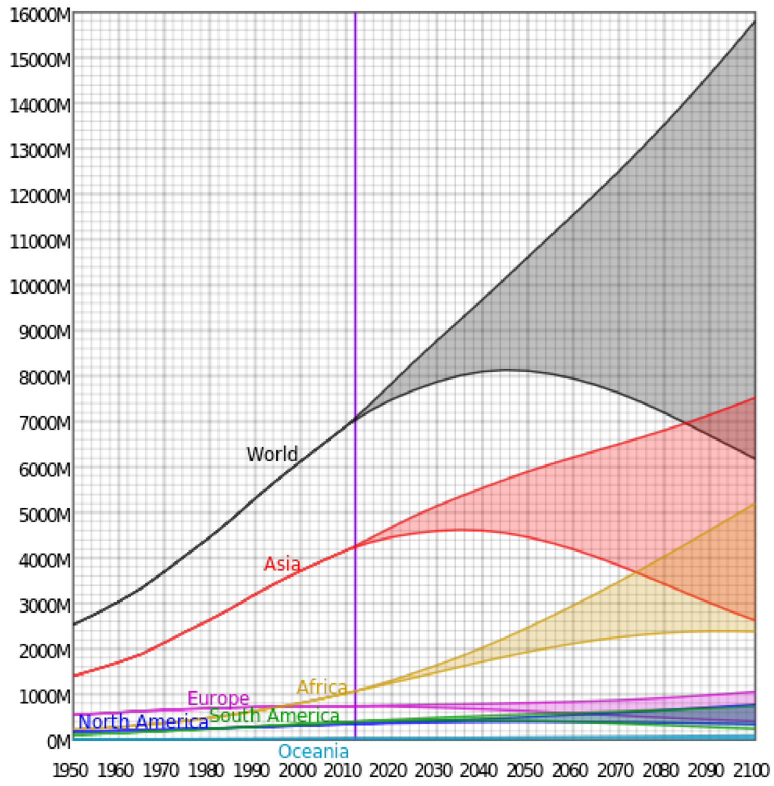
- The "Anthropocene" Era
  - Somewhat dated, but very influential paper
  - Root cause of all global change is ↑ human population & ↑ in quality of life (&, therefore, resource consumption)

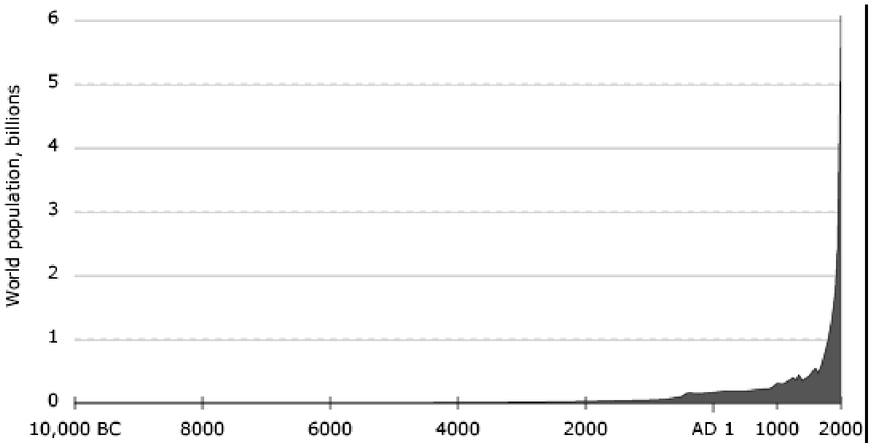


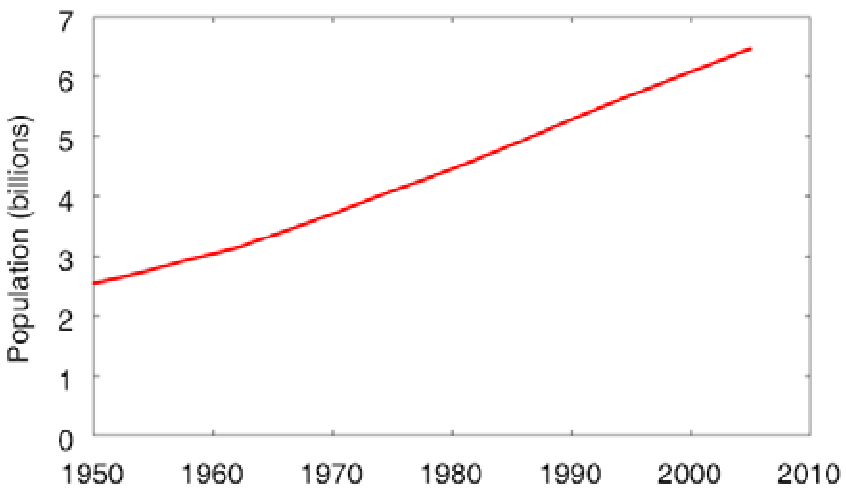
Vitousek *et al*. 1997

Restoration in the Context of Global Change

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

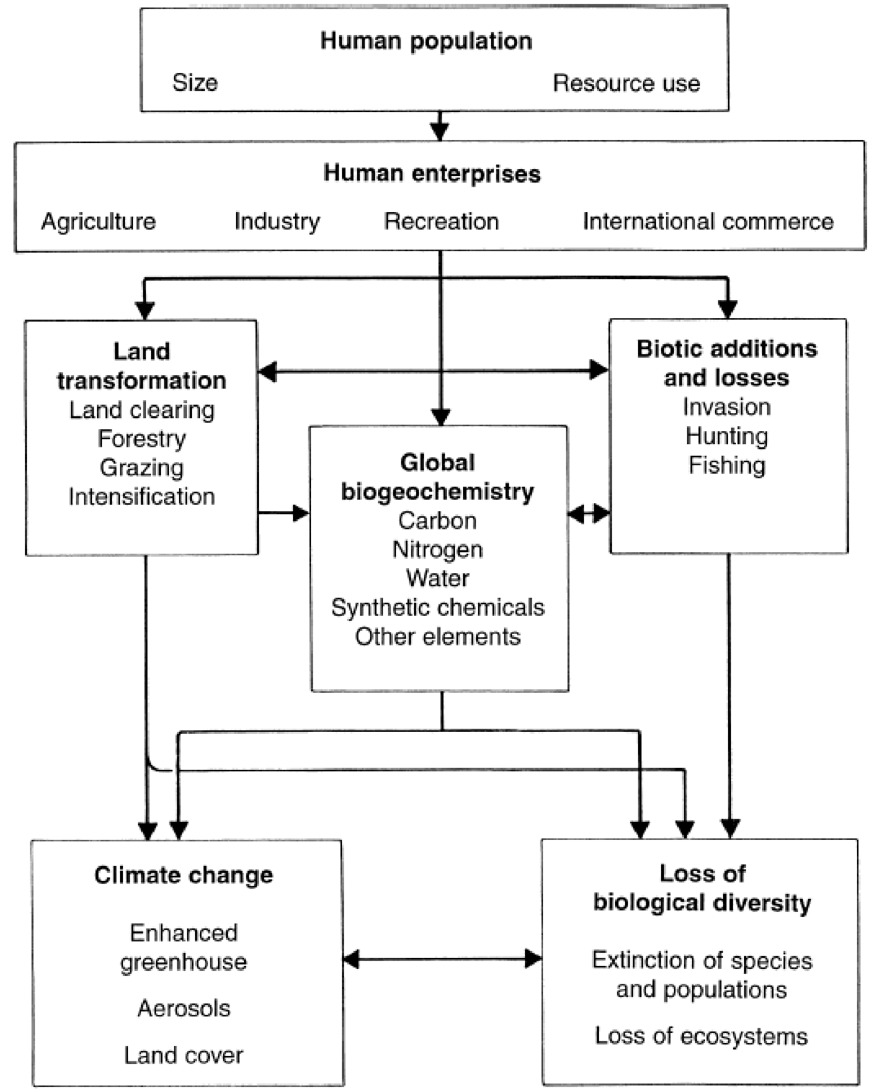






Restoration in the Context of Global Change

- Direct and indirect influence of humans on the Earth system
  - As populations / quality of life / resource consumption increase, necessarily so do human enterprises to support a burgeoning population



Vitousek *et al*. 1997

Restoration in the Context of Global Change

- Land transformations (39-50% of Earth's surface; not always easily observed)
  - Row crop agriculture and urbanization (10-15%)
  - Conversion to pastureland (6-8%)
  - Grazing by domestic animals and extraction of wood products (25%???)

Ag. Land in Midwest

Urban Dev. in HI

Grazing in HI

Clearcut in SE U.S.

Restoration in the Context of Global Change

- Implications of land transformation for restoration
  - Habitat loss and fragmentation
    - 1° driving force behind loss of biodiversity
    - Alters genetic diversity & population dynamics
    - Fragments landscapes
    - Alters local and regional climate
    - Increases atmospheric CO_2 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 www.oahunaturetours.com
Kauai O'O Extinct, Kauai Akialoa Extinct, O'u Extinct,
Kauai Nukupu'u Extinct, Puaiohi less then 200 remain, Kamao Extinct

Restoration in the Context of Global Change

- Alteration of biodiversity – Additions (invasive species; + initially, but can be + or - in long-term)

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 & biotic interactions
    - Two primary factors shaping communities

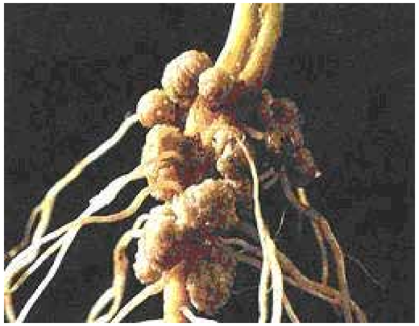
      - Extinctions
        - Loss of pollinators, seed dispersers, etc.
        - Loss of keystone species
        - Alterations in structure & function of ecological systems

      - Invasions
        - 2nd 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



N deposition

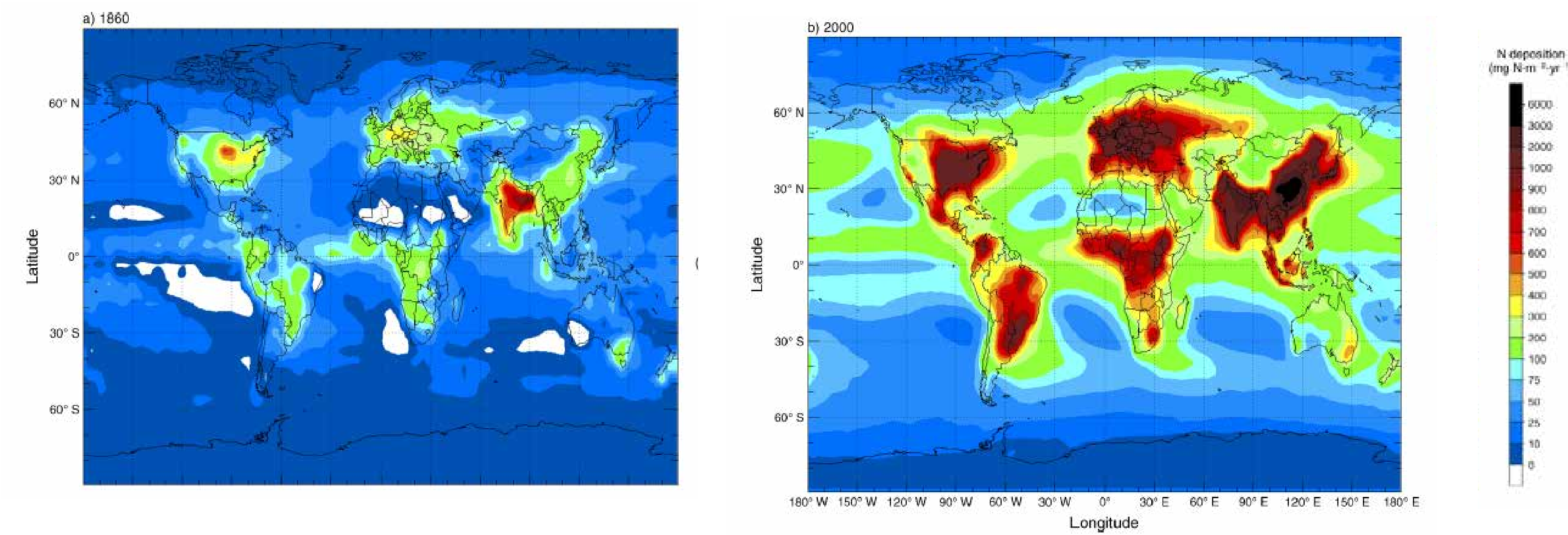
← Natural →

vs.

← Anthropogenic →

Restoration in the Context of Global Change

- Alteration of biogeochemical cycles – Nitrogen
  - N Deposition (wet & dry): 0.2-0.5 g N m^{-2} yr^{-1} in undisturbed systems
  - Rates now 10-100x higher than background rates



Bobbink *et al*. 2010

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 for an important belowground resource (commonly a limiting resource)
  - Leads to N saturation and toxicity
  - Alters coupled biogeochemical cycles
    - E.g., calcium deficiencies now widespread in many temperate forests
  - Potent greenhouse gases → global climate change

Restoration in the Context of Global Change

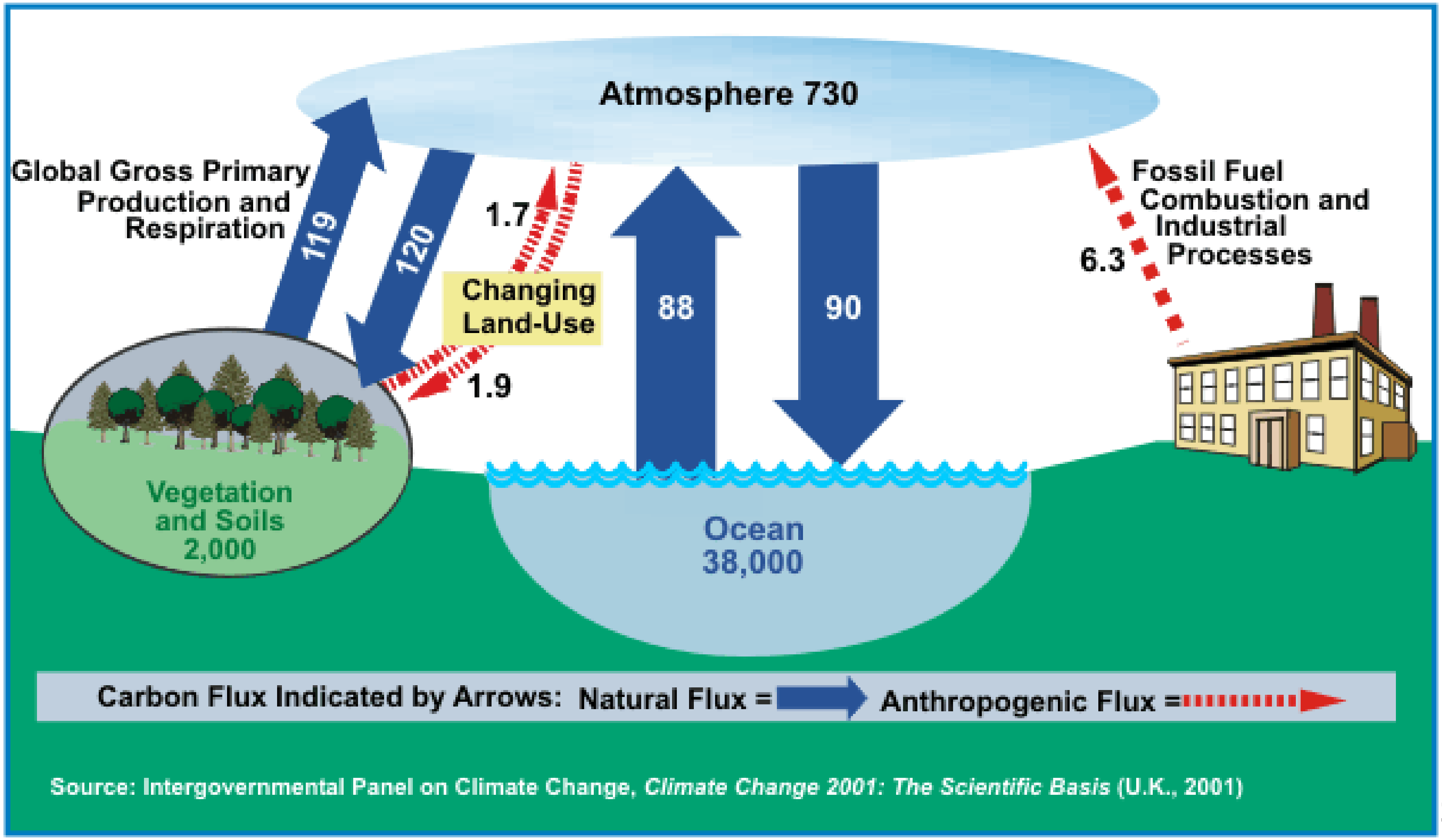
- Alteration of biogeochemical cycles - Water

Restoration in the Context of Global Change

- Implications of altered H_2O cycling for restoration
  - Alters availability and use of H_2O in ecological systems
    - Changes competitive interactions for an important belowground resource (commonly a limiting resource)
  - Alters precipitation regimes at local and regional scales
  - H_2O is <u>the</u> major greenhouse gas

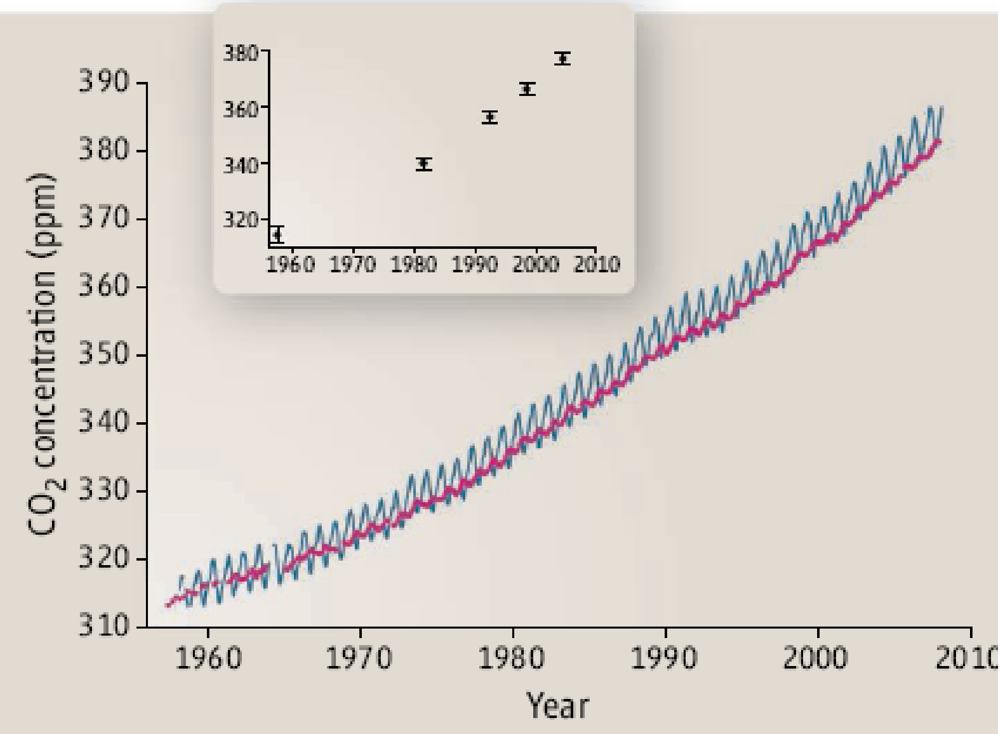
Restoration in the Context of Global Change

- Alteration of biogeochemical cycles - Carbon



Restoration in the Context of Global Change

- Increased atmospheric CO_2 concentrations
- Globally, result of:
  - Fossil fuel emissions (~2/3)
  - Land Transformations (~1/3)
  - ~50% of human C emissions have been taken up by land (~25%) and sea (~25%)



Keeling 2008

Restoration in the Context of Global Change

- Implications of altered C cycling for restoration
  - Changes in C cycling alter:
    - Global Climate
      - Species distributions (regional and local species pools)
        - Competitive interactions
      - Ecosystem structure and function
    - Atmospheric CO_2 concentrations
      - Competitive interactions

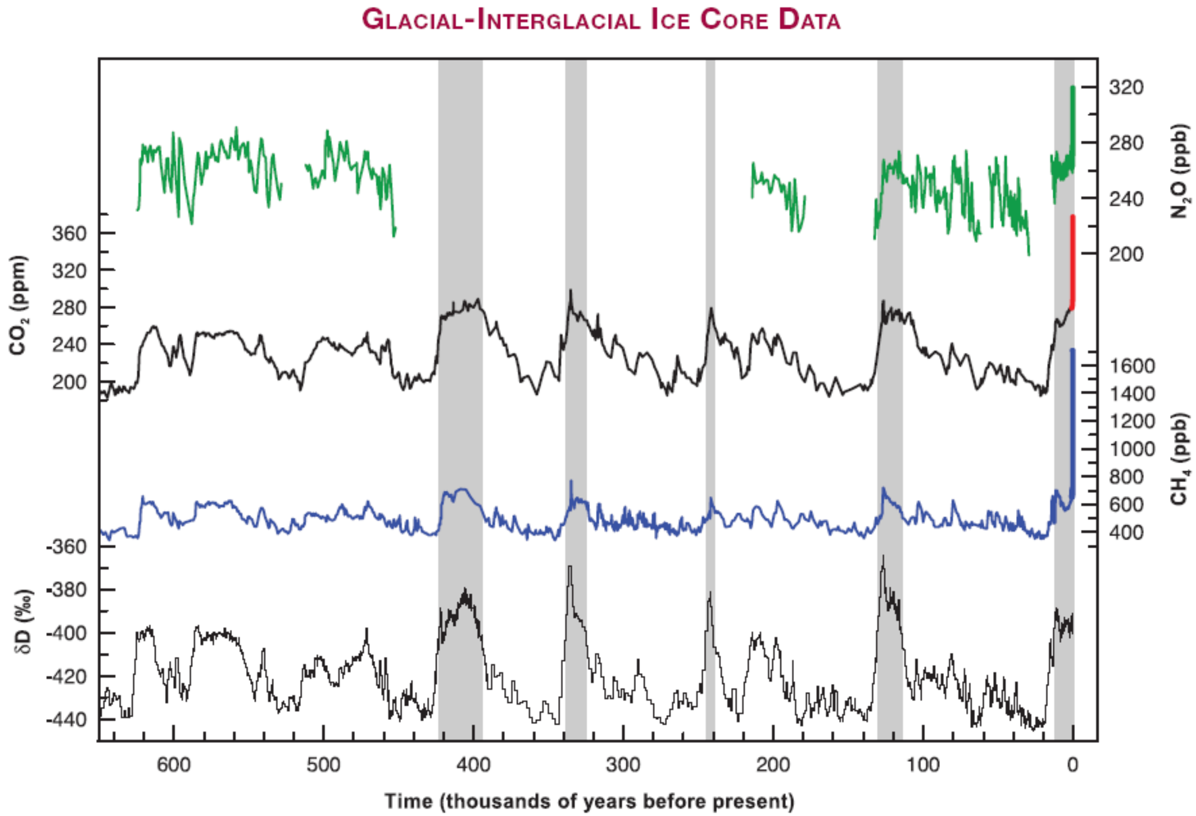
Restoration in the Context of Global Change

- Weather vs. climate; Imp. distinction
- 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 reasonable 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?
    - How can we slow down, and manage for, climate change?

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?

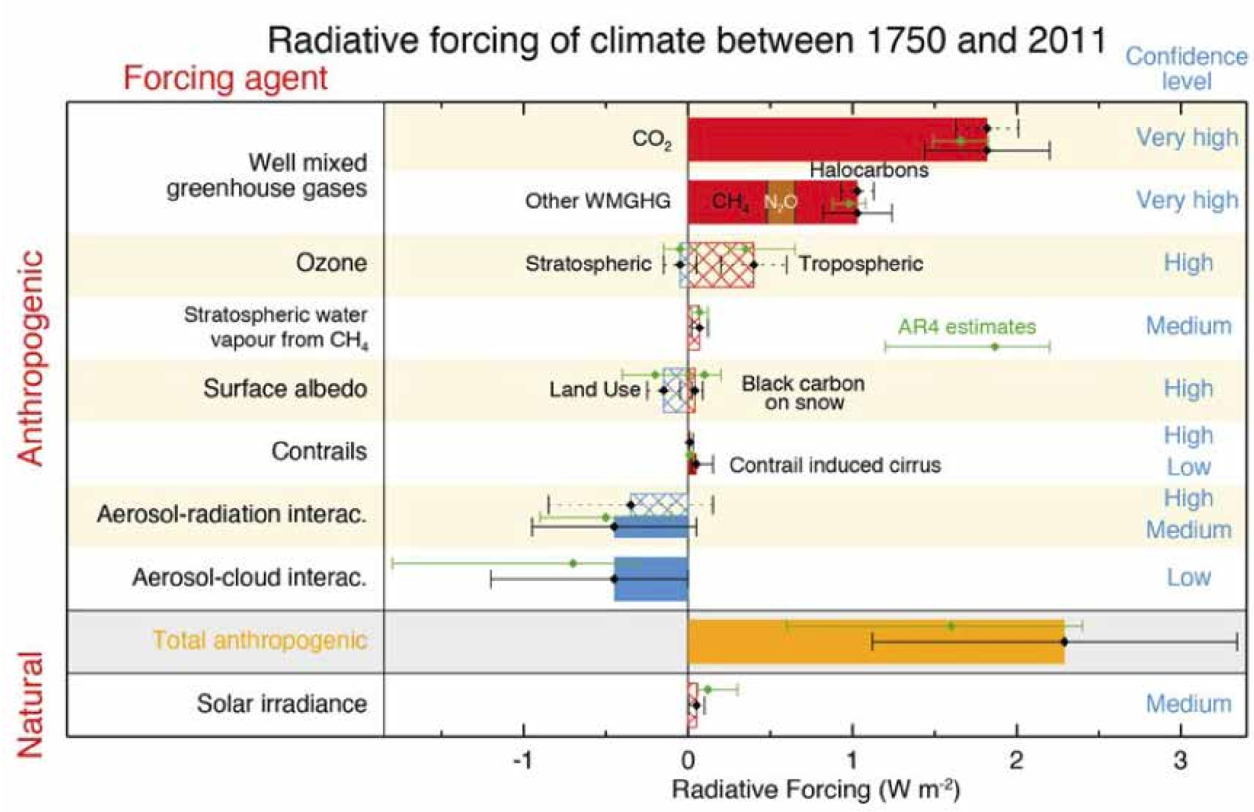
- Paleo records (e.g., ice cores)
  - Strong correlation between greenhouse gas conc. and temp.
  - Higher conc. of CO_2, CH_4, and N_2O than anytime in the past 800,000 years
  - Biosphere has taken up ~50% of CO_2 emissions
  - Large temporal fluctuations



IPCC 2007

Restoration in the Context of Global Change

- This is why we talk so much about CO_2 in the context of climate change!
  - Other factors clearly important
  - Lots of uncertainty in some factors



IPCC 2013

Restoration in the Context of Global Change

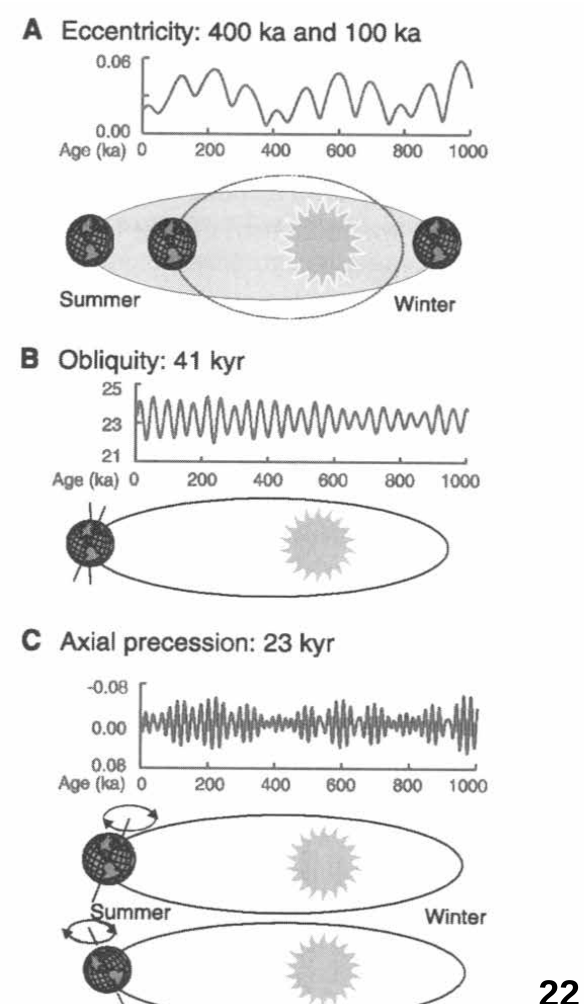
- Earth Climate System – Natural fluctuations

Multi-millennial climate cycles (glacial/interglacial; orbital; Milankovitch cycles)

A. ° of ellipticity of orbit (100,000 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)



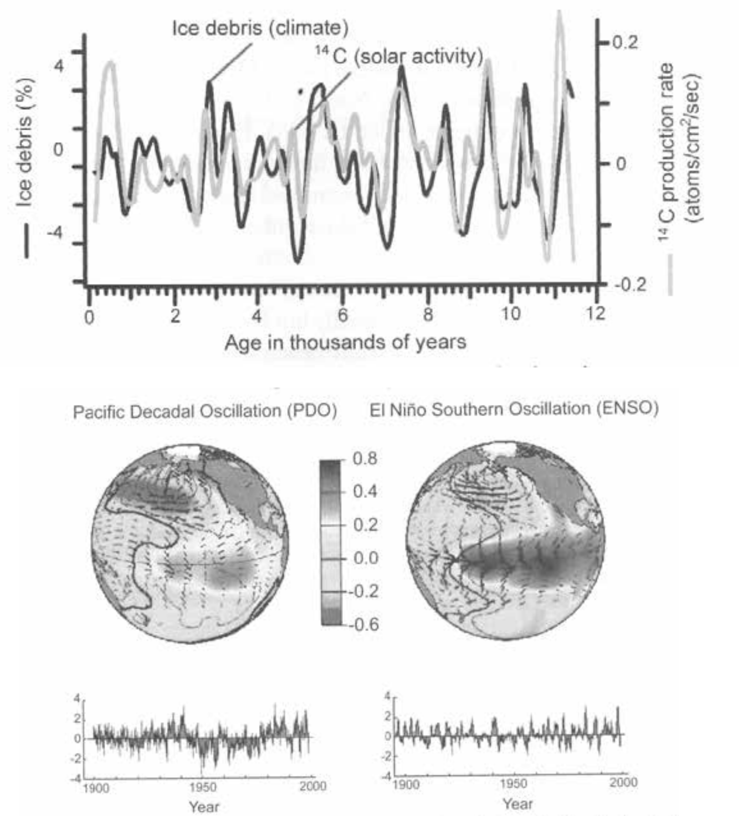
Millar & Brubaker (2006)

Restoration in the Context of Global Change

- Earth Climate System – Natural fluctuations

- Century to millennial scale cycles
  - Bond Cycles (1,300-1,500 year cycle)
  - Explain much of the climate variability within multi-millennial scales
  - Begin and end very abruptly
  - Changes in intensity of solar radiation

- Interannual to decadal scale cycles
  - PDO (multidecadal; 20-60 year cycle)
  - ENSO (interannual; 2-8 year cycle)

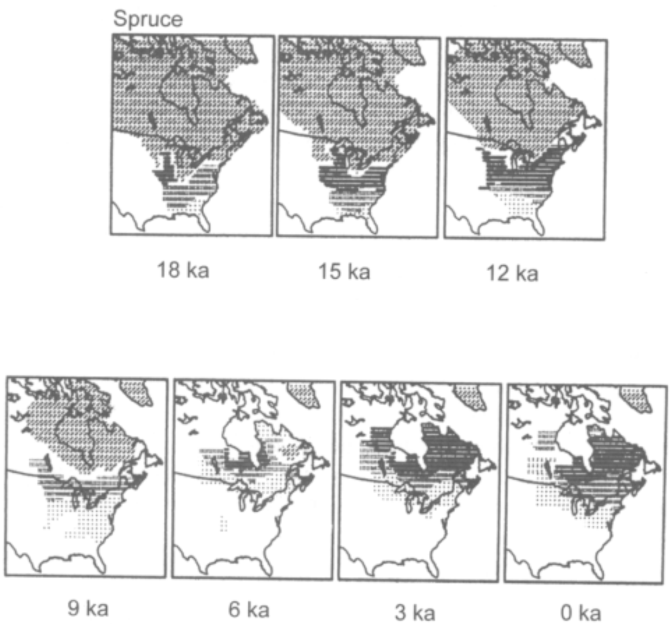


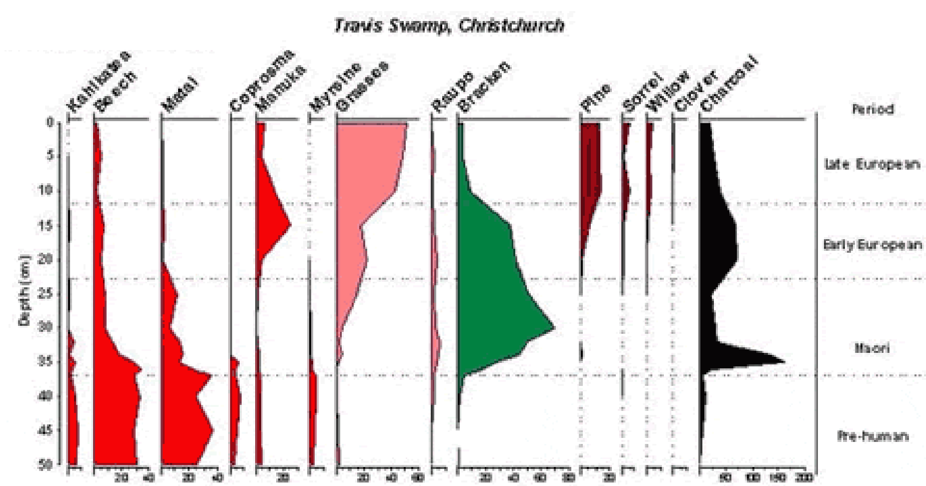
Millar & Brubaker (2006)

Restoration in the Context of Global Change

- Climate has varied naturally in the past, so why should we care if it is changing now?

- Ecological systems respond strongly to climate change
  - Complete species turnover
  - Recurring patterns of similar groups of species over time at coarse scales
  - **Species respond individualistically to a changing climate**
    - Lag phases; No-analog communities; Novel ecosystems





Millar & Brubaker (2006)

Restoration in the Context of Global Change

- Climate has varied naturally 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 can occur very 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 varied naturally in the past, so why should we care if it is changing now?

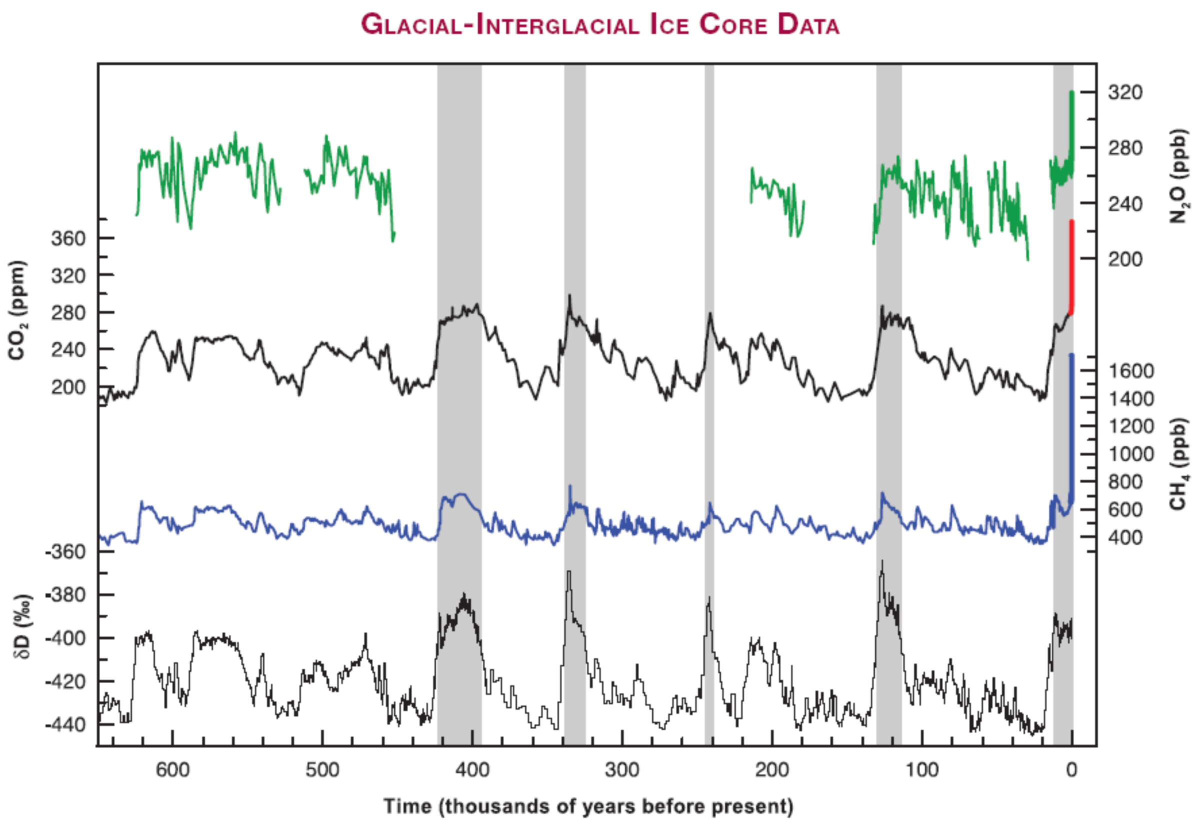
- Scientific consensus is that climate is changing, and that this change is primarily a result of human activity
  - *Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased* (IPCC 2013)

  - *Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system* (IPCC 2013)

  - Similar statements from The National Academy of Sciences, The American Meteorological Society, the American Geophysical Union, and the American Association for the Advancement of Science (AAAS)

Restoration in the Context of Global Change

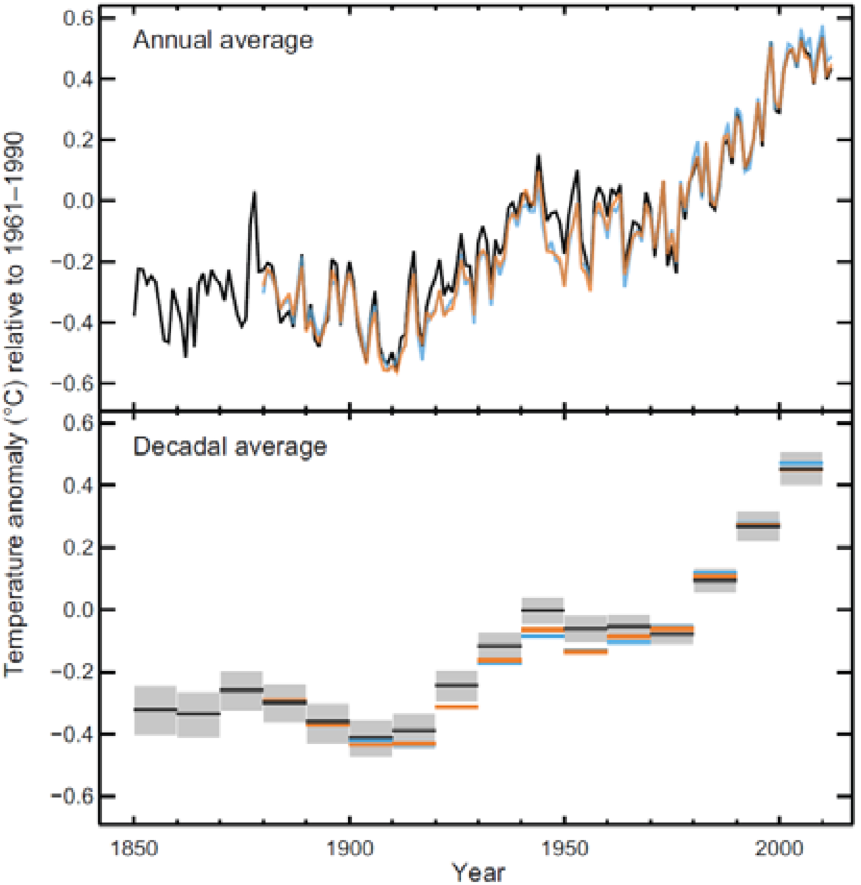
- Climate has varied naturally in the past, so why should we care if it is changing now?
  - Rate of change far exceeds that from anytime in the past
    - Prior to 1750, CO_2 increased by 20 ppm over 8,000 years
    - Since 1750, CO_2 has increased by >100 ppm



(IPCC 2007)

Restoration in the Context of Global Change

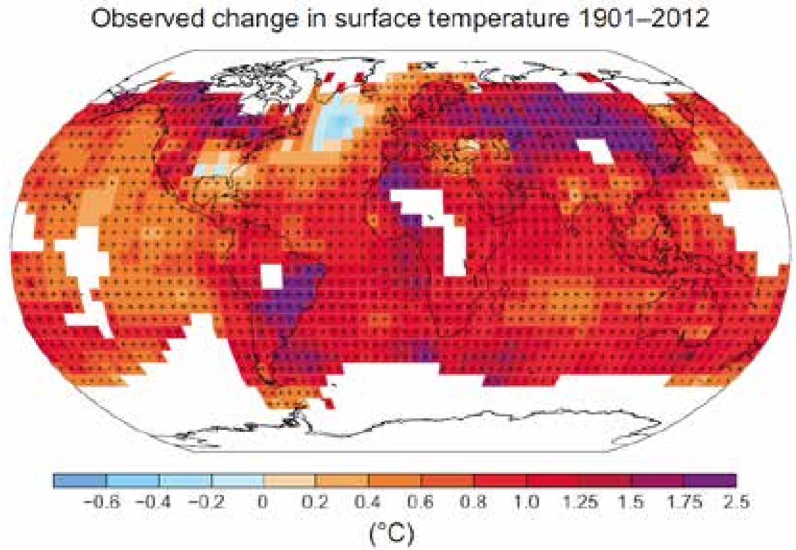
- Observed temperature change
  - Increasing for >150 years
  - Accelerating rate of increase
- What's the big deal about a ~5°C temperature increase?
  - Difference between glacial & interglacial is ~15°C

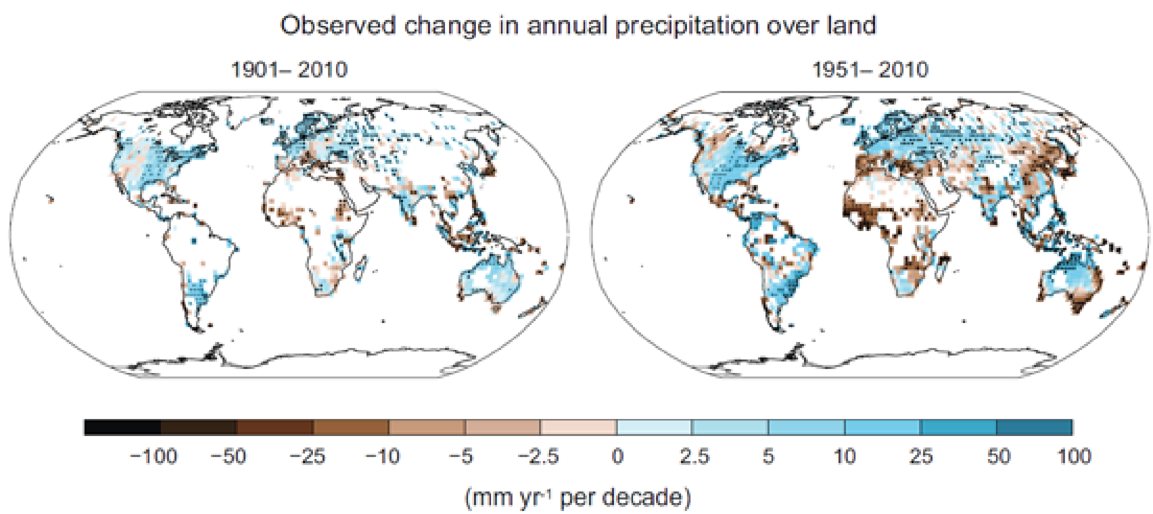


IPCC 2013

Restoration in the Context of Global Change

- Climate Change will not impact all areas equally

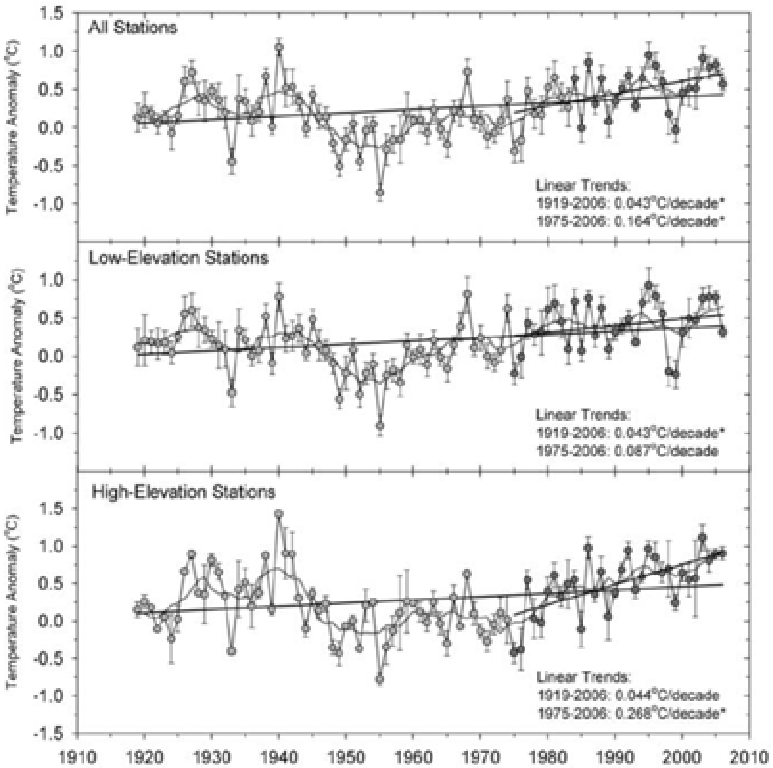




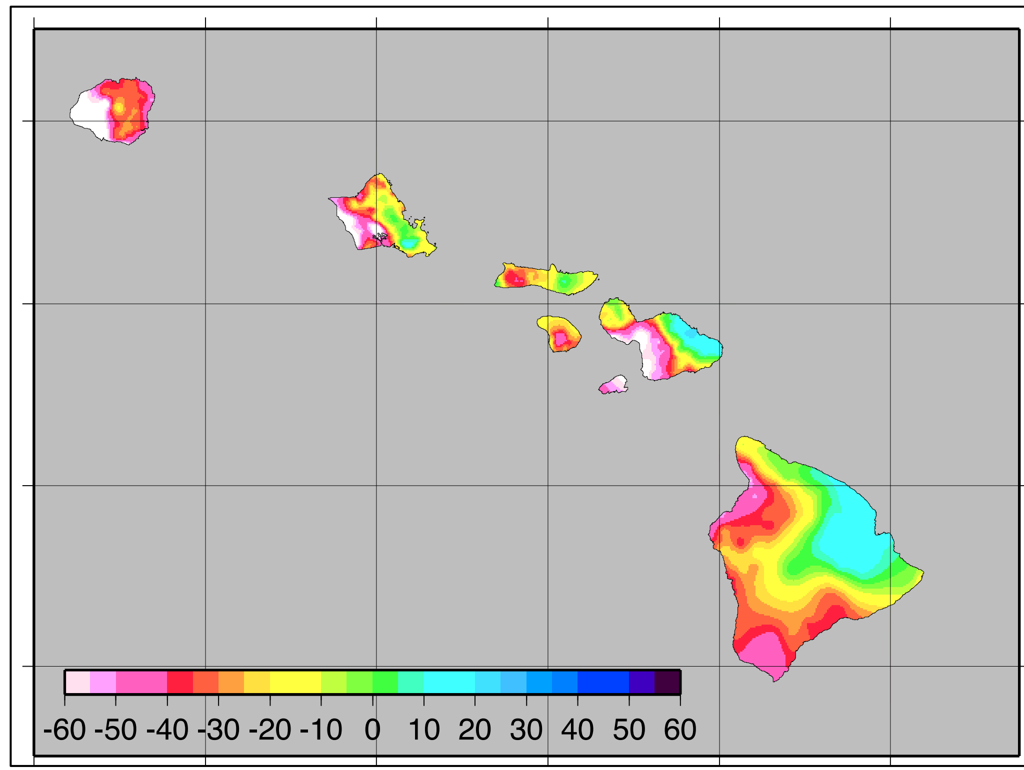
IPCC 2013

Restoration in the Context of Global Change

- Climate change in Hawaii
  - Island ecosystems initially thought to be “protected” by ocean



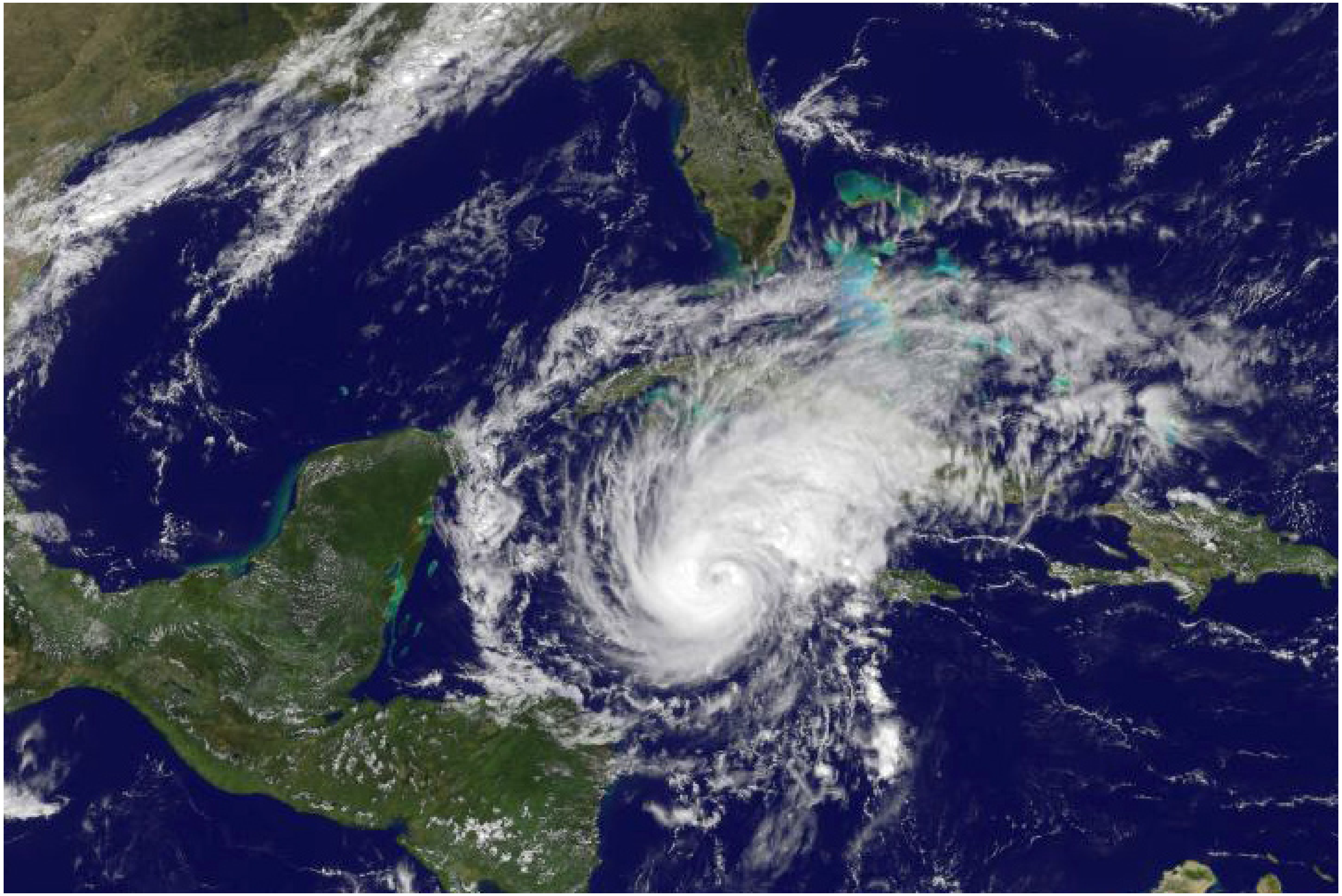
HI Temperature (Giambelluca et al. 2008)



HI Precipitation (Elison Timm *et al*. 2015)

Restoration in the Context of Global Change

- Projected changes in the occurrence and intensity of natural disturbances

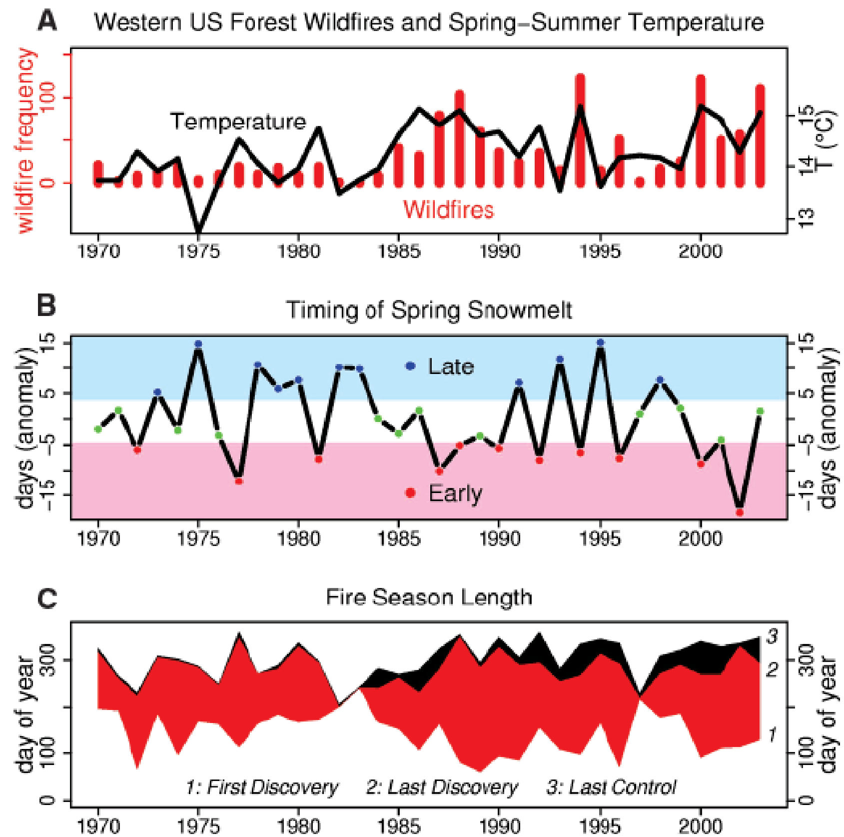


NASA 2008

Restoration in the Context of Global Change

- Will climate change 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.



Westerling *et al*. 2006

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)
      - …*ecological conditions are not in equilibrium, do not remain stable, nor are they sustained, but, by contrast, are in ongoing flux*
  - More rapid change in a highly fragmented landscape?
  - More frequent "extreme" (i.e., stochastic) events?
  - Changes in disturbance regimes?

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*"
  - Climate change (natural and current) changes the playing field for reference endpoints/trajectories
    - Manage for ecological & evolutionary adaptation to prevailing/past conditions vs. future conditions?
      - Future conditions may differ greatly, and current climate change is occurring at unprecedented rates
      - Restore static historical systems or realign systems to current, or even future anticipated, conditions?
        - Sustain future options for adaptation to change, and not stable conditions that resist change

Week 12 Readings/Lecture Slide Highlights

1. The factors that collectively comprise global change biology (i.e., planetary-scale changes in the Earth system arising from human activities) are so widespread and pervasive that all current and future ecological restoration should be planned explicitly with these factors in mind. For most systems, this means that planning should be done based on current and future anticipated conditions, and not past conditions which is what most reference ecosystems represent.

Week 12 Readings/Lecture Slide Highlights

2. Anthropogenic activities have increased nitrogen deposition by 10-100x over natural background levels. Nitrogen deposition increases the availability of what is one of the most limiting resources in ecological systems. This, in turn, alters biotic interactions (e.g., competitive dynamics) and species composition, as well as resulting in increased production of important N-containing greenhouse gases.

Week 12 Readings/Lecture Slide Highlights

3. Fossil fuel emissions (~2/3) and land use change (~1/3) increase global greenhouse gas (CO_2) concentrations, and lead to warming of the Earth's atmosphere (i.e., climate change). Climate is the most important determinant of species distributions and rates of ecological processes. Therefore, a changing climate will alter species distribution and ecological process rates.

Week 12 Readings/Lecture Slide Highlights

4. Climate on Earth has changed drastically over the past 2.5 million years, and likely for millions of years prior to that, alternating between glacial and interglacial periods in step with cyclical changes in Earth’s orbit. Current climate change, however, is human-caused and unique in terms of the unprecedented rate of change.

Week 12 Readings/Lecture Slide Highlights

5. Plant communities are transient assemblages of species, where species respond individualistically to changes in climate (and other driving environmental variables). As such, the dispersal of species across the landscape with current climate change will most likely result in novel or no-analog ecosystems, with important implications for conservation and restoration activities and planning.