Climate Impacts

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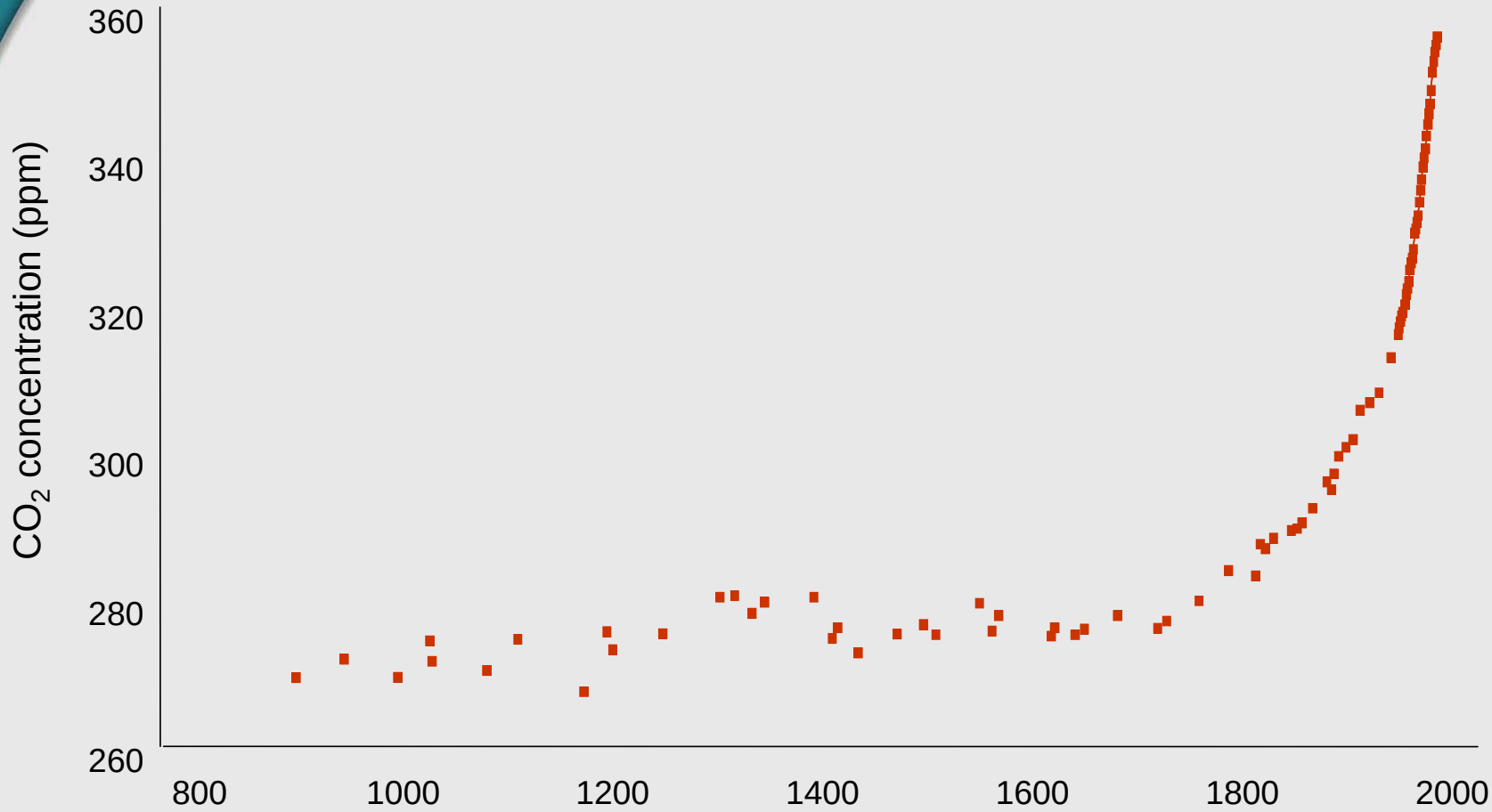
Thoughts on Uncertainties: Focus on the Important

- Acknowledge uncertainties in science, but manage the risks
- Focus on what's really important

Global CO_2 Concentration



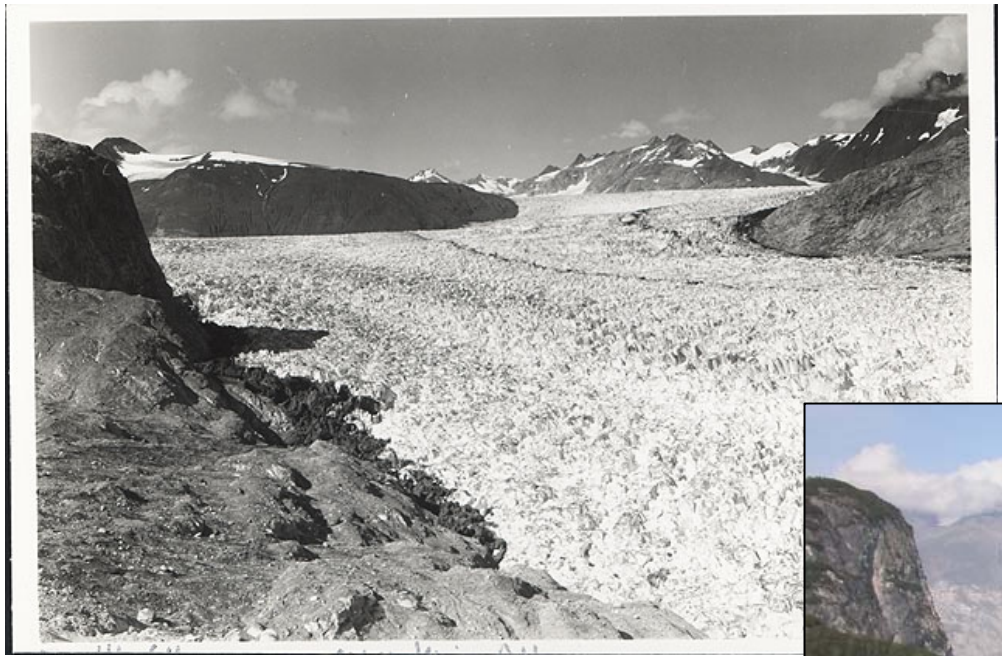
2007 IPCC Conclusions

- The observed change in the climate system over roughly the past century is virtually certain to be due in part to human influences.
- The observed changes in climate are very likely to continue, and even accelerate during the current century.
- There are now many observed, well-documented impacts of changes in natural resources, animal and plant species, and ecosystems in many regions of the world.
- Impacts in the future are very likely to grow in both number and magnitude.
- Climate change and its impacts present challenges for adaptation in both the developing world, and as well among developed countries.

Grinnell Glacier, Glacier National Park
Late summer of 1938 (left) and 1981 (right)

Source: http://nrmsc.usgs.gov/research/glacier_retreat.htm

Muir Glacier, Alaska
August 1941 (left) and August 2004 (right)



Source: National Snow and Ice Data Center (www.nsidc.org)

Source: WWF

Arctic Climate Impact Assessment Findings

- Arctic climate is warming rapidly and larger changes are projected
- Arctic warming and its consequences have worldwide implications
- Arctic vegetation zones are very likely to shift, causing wide-ranging impacts
- Animal species' diversity, ranges, and distribution will change
- Many coastal communities and facilities face increasing exposure to storms

Arctic Climate Impact Assessment Findings

- Reduced sea ice is very likely to increase marine transport and access to resources
- Thawing ground will disrupt transportation, buildings, and other infrastructure
- Indigenous communities are facing major economic and cultural impacts

Arctic Climate Impact Assessment Findings

- Elevated ultraviolet radiation levels will affect people, plants, and animals.
- Multiple influences interact to cause impacts to people and ecosystems

New Findings from CCSP Synthesis and Assessments

- Major report on climate change impacts on US ecosystems to be released next week
- Preview of major findings and conclusions

Findings: Agriculture

- With increased CO_2 and temperature, the life cycle of grain and oilseed crops will likely progress more rapidly.
- As temperature rises, these crops will increasingly begin to experience failure, especially if climate variability increases and precipitation lessens or becomes more variable.
- The marketable yield of many horticultural crops – e.g. tomatoes, onions, fruits – is very likely to be more sensitive to climate change than grain and oilseed crops.
- Climate change is likely to lead to a northern migration of weeds. Many weeds respond more positively to increasing CO_2 than most cash crops, particularly C3 "invasive" weeds.
- Disease pressure on crops and domestic animals will likely increase with earlier springs and warmer winters, which will allow proliferation and higher survival rates of pathogens and parasites.
- Higher temperatures will very likely reduce livestock production during the summer season. For ruminants, current management systems generally do not provide shelter to buffer the adverse effects of changing climate; such protection is more frequently available for non-ruminants (e.g., swine and poultry).

Findings: Forest Land Resources

- Climate change has very likely increased the size and number of forest fires, insect outbreaks, and tree mortality in the interior west, the Southwest, and Alaska, and will continue to do so.
- Rising CO_2 will very likely increase photosynthesis for forests, but the increased photosynthesis will likely only increase wood production in young forests on fertile soils.
- Nitrogen deposition and warmer temperatures have very likely increased forest growth where adequate water is available and will continue to do so in the near future.
- The combined effects of rising temperatures and CO_2, nitrogen deposition, ozone, and forest disturbance on soil processes and soil carbon storage remains unclear.

Findings: Arid Lands

- Higher temperatures, increased drought, and more intense thunderstorms will very likely increase erosion and promote invasion of exotic grass species in arid lands.
- Climate change is expected to increase fire frequency in arid lands with improved physical conditions for wildfire, and the proliferation of exotic grasses providing fuel.
- Increases in fire will increase the risk of loss of iconic, charismatic plants, such as saguaro cacti and Joshua trees, that have not co-evolved with fire.
- Arid lands very likely do not have a large capacity to absorb CO_2 from the atmosphere and will likely lose carbon as climate-induced disturbance increases.
- River and riparian ecosystems in arid lands will very likely be negatively impacted by decreased streamflow, increased water removal, and greater competition from nonnative species.
- Changes in temperature and precipitation will very likely decrease the cover of vegetation that protects the ground surface from wind and water erosion.

Findings: Water Resources

- Most of the United States experienced increases in precipitation and streamflow and decreases in drought during the second half of the 20th century. It is likely that these trends are due to a combination of decadal-scale variability and long-term change.

- Consistent with streamflow and precipitation observations, most of the continental United States experienced reductions in drought severity and duration over the 20th century. However, there is some indication of increased drought severity and duration in the western and southwestern United States.

- We are observing a trend of reduced mountain snowpack, and earlier spring snowmelt runoff peaks across much of the western United States. This trend is very likely attributable, at least in part, to long-term warming, although some part may have been played by decadal scale variability, including shift in the Pacific Decadal Oscillation in the late 1970s.

Findings: Water Resources

- Where earlier snowmelt peaks and reduced summer and fall low flows have already been detected, continuing shifts in this direction are very likely and may have substantial impacts on the performance of reservoir systems.

- Trends toward increased water use efficiency are likely to continue in the coming decades. Pressures for reallocation of water will be greatest in areas of highest population growth, such as the Southwest. Declining per capita (and, for some cases, total) water consumption will help mitigate the impacts of climate change on water resources.

- A suite of climate simulations conducted for the IPCC show that the United States may experience increased runoff in eastern regions, gradually transitioning to little change in the Missouri and lower Mississippi, to substantial decreases in annual runoff in the interior of the west (Colorado and Great Basin).

Findings: Biodiversity

- There has been a significant lengthening of the growing season and increase in net primary productivity (NPP) in the higher latitudes of North America. Over the last 19 years, global satellite data indicate an earlier onset of spring across the temperate latitudes by 10 to 14 days.
- Corals in many tropical regions are experiencing substantial mortality from increasing water temperatures, increasing storm intensity, and a reduction in pH, on top of a host of other ongoing challenges from development and tourism, fishing, and pollution.
- The rapid rates of warming in the Arctic observed in recent decades, and projected for at least the next century, are dramatically reducing the snow and ice covers that provide denning and foraging habitat for polar bears.
- There are other possible, and even probable, impacts and changes in biodiversity (e.g. disruption of the relationships between pollinators, such as bees, and flowering plants), for which we do not yet have a substantial observations.

Overarching Conclusions

- **Climate changes – temperature increases, increasing CO_2 levels, and altered patterns of precipitation – are already affecting U.S. water resources, agriculture, land resources, and biodiversity (*very likely*).**

Overarching Conclusions

- **Climate change will continue to have significant effects on these resources over the next few decades and beyond (*very likely*).**

- **Many other stresses and disturbances are also affecting these resources (*very likely*)**

Overarching Conclusions

- **Climate change impacts on ecosystems will affect the services that ecosystems provide, such as cleaning water and removing carbon from the atmosphere *(very likely)*, but we do not yet possess sufficient understanding to project the timing, magnitude, and consequences of many of these effects.**

Overarching Conclusions

- **Existing monitoring systems, while useful for many purposes, are not optimized for detecting the impacts of climate change on ecosystems.**

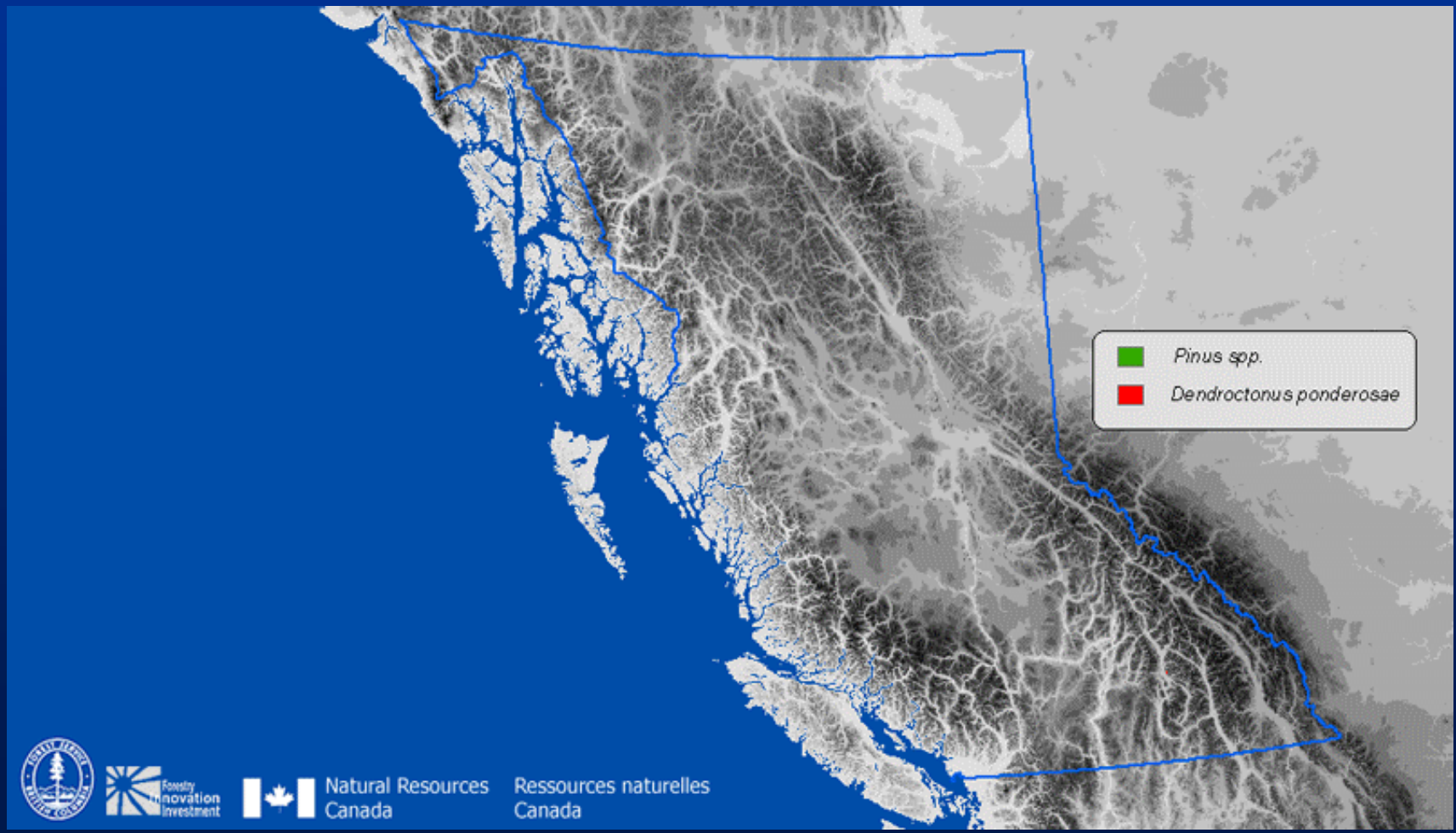
A Major Strategic Challenge

- Understanding the speed, magnitude, and potential for irreversibility of the impacts of climate change
- Of particular concern are those impacts that arise rapidly, result in extremely large changes in resources, or are irreversible in nature, and therefore are difficult to predict
- I.e. those impacts that appear to be the results of crossing thresholds or tipping points in ecosystems

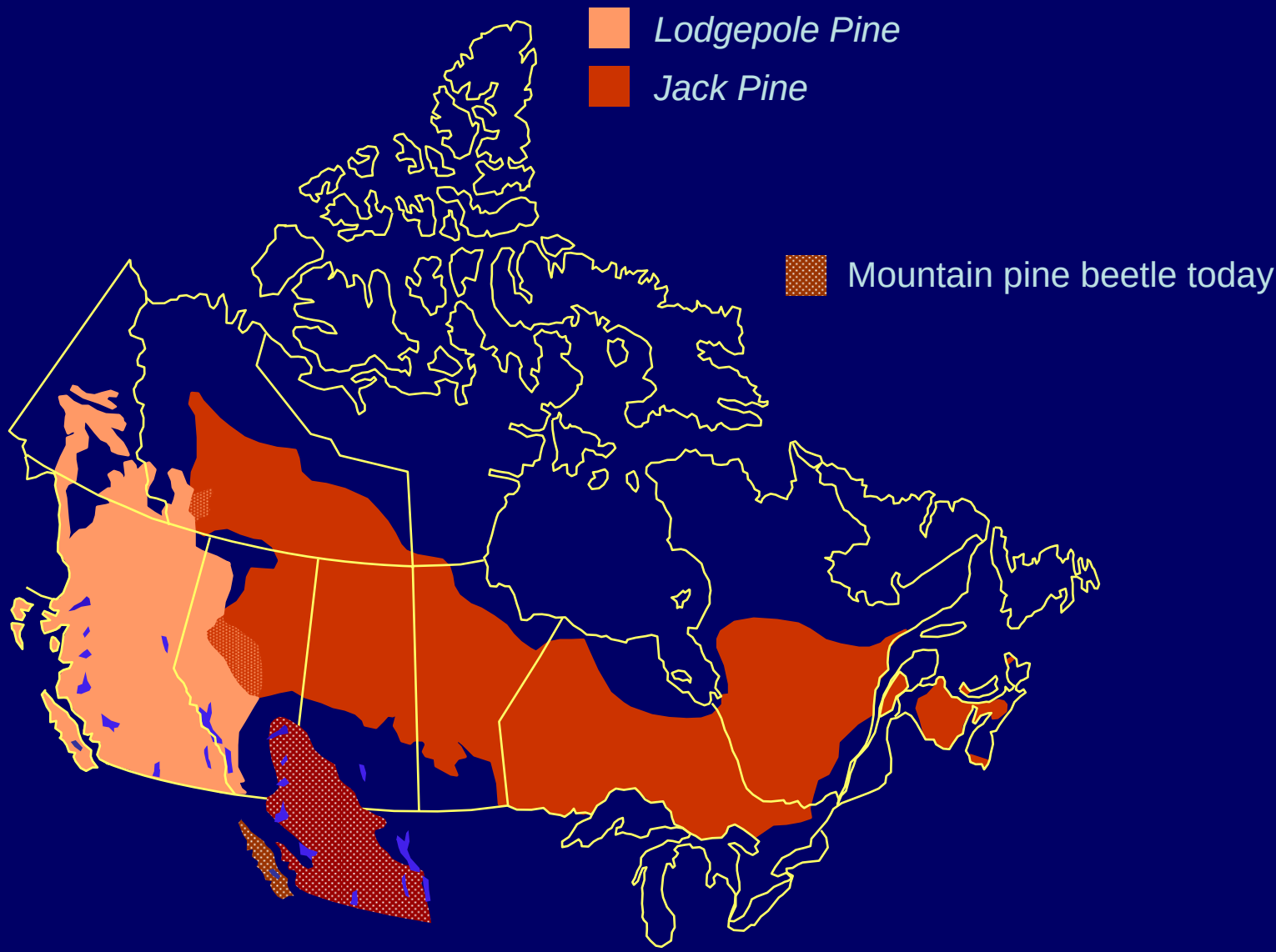
Mountain Pine Beetle
(M. Bradley, Canfor Pulp)

- Native to Lodgepole pine forests of western N. America
- Natural part of the disturbance ecology of Montane forests
- Periodic outbreaks
- Previous largest recorded outbreak 650,000 ha during 1930's

Mountain Pine Beetle outbreaks (1959-2002)



Could MPB spread through the boreal forest of N. America?



Source: NRCan/CFS/PFC

No climate (?) or biological barriers to MPB

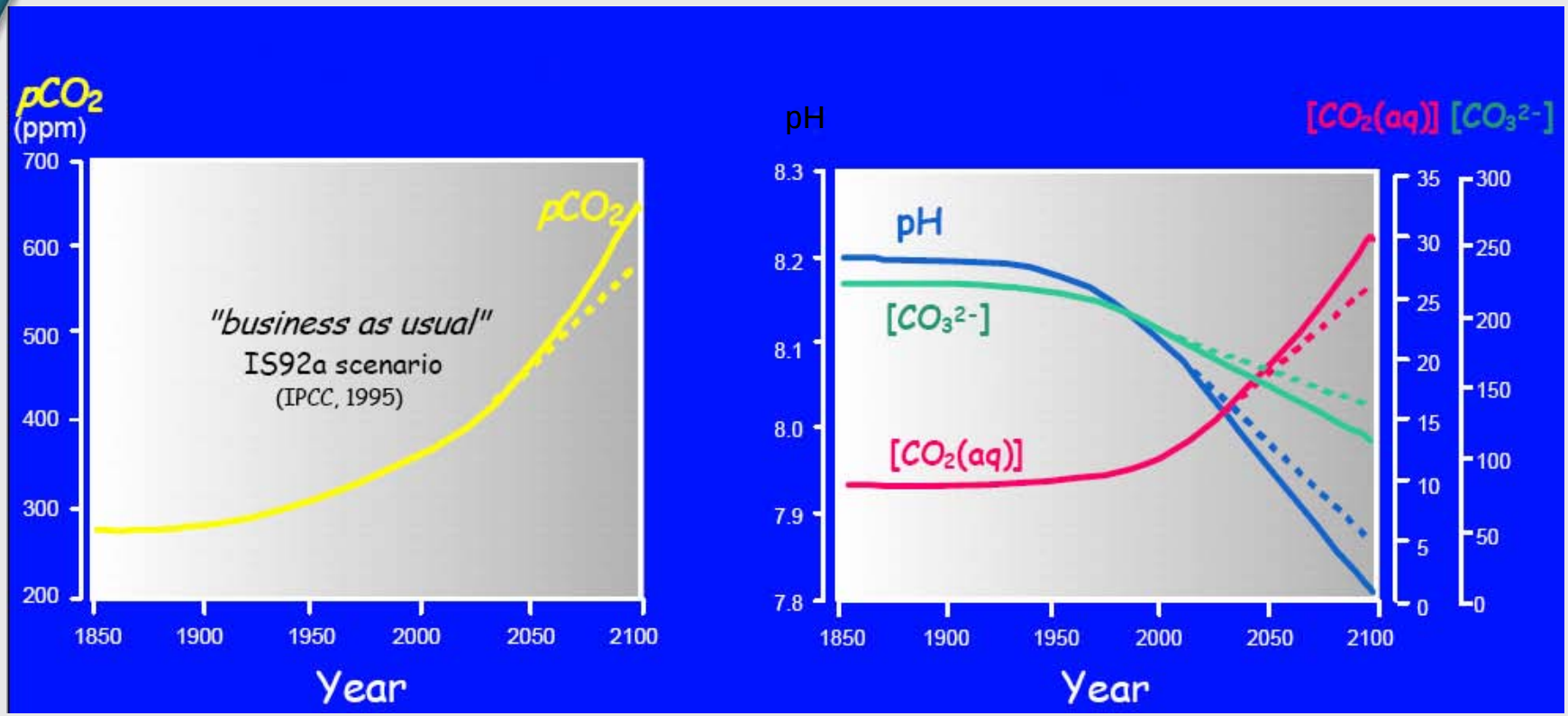
Type 1: well understood cases where response is well documented	
Peruvian anchovy	*Kenny Broad, U. of Miami*
Mesquite invasion	*Brandon Bestelmeyer, USDA-ARS, NMSU*
Type 2: ongoing cases exhibiting accelerating change	
Sea-level rise	*Jeff deBlieu, The Nature Conservancy*
Drought- Columbia River Basin	*Ed Miles, U. of Washington*
Drought- Colorado River Basin	*Roger Pulwarty, NOAA*
Forest die-off- U.S. West	*David Breshears, U. of Arizona*
Forest die-off African Sahel	*Patrick Gonzalez, The Nature Conservancy*
Coral Reefs	*Phil Kramer, The Nature Conservancy*
Mountain Pine Beetle	*Mike Bradley, Canfor Pulp and Paper*
Type 3: Major systemic change	
Ocean Acidification	*Richard Feely, NOAA*
Terrestrial Carbon Sink	*Lisa Dilling, Center for Science and Technology Policy Research, U. of Colorado*

Emerging Issues and Context

- Ecological impacts are still emerging from the noise
- Entirely new issues are also arising
- Keep in mind that climate impacts must be viewed in a broader context of other environmental changes

Rising atmospheric CO_2 is changing the chemistry of the ocean

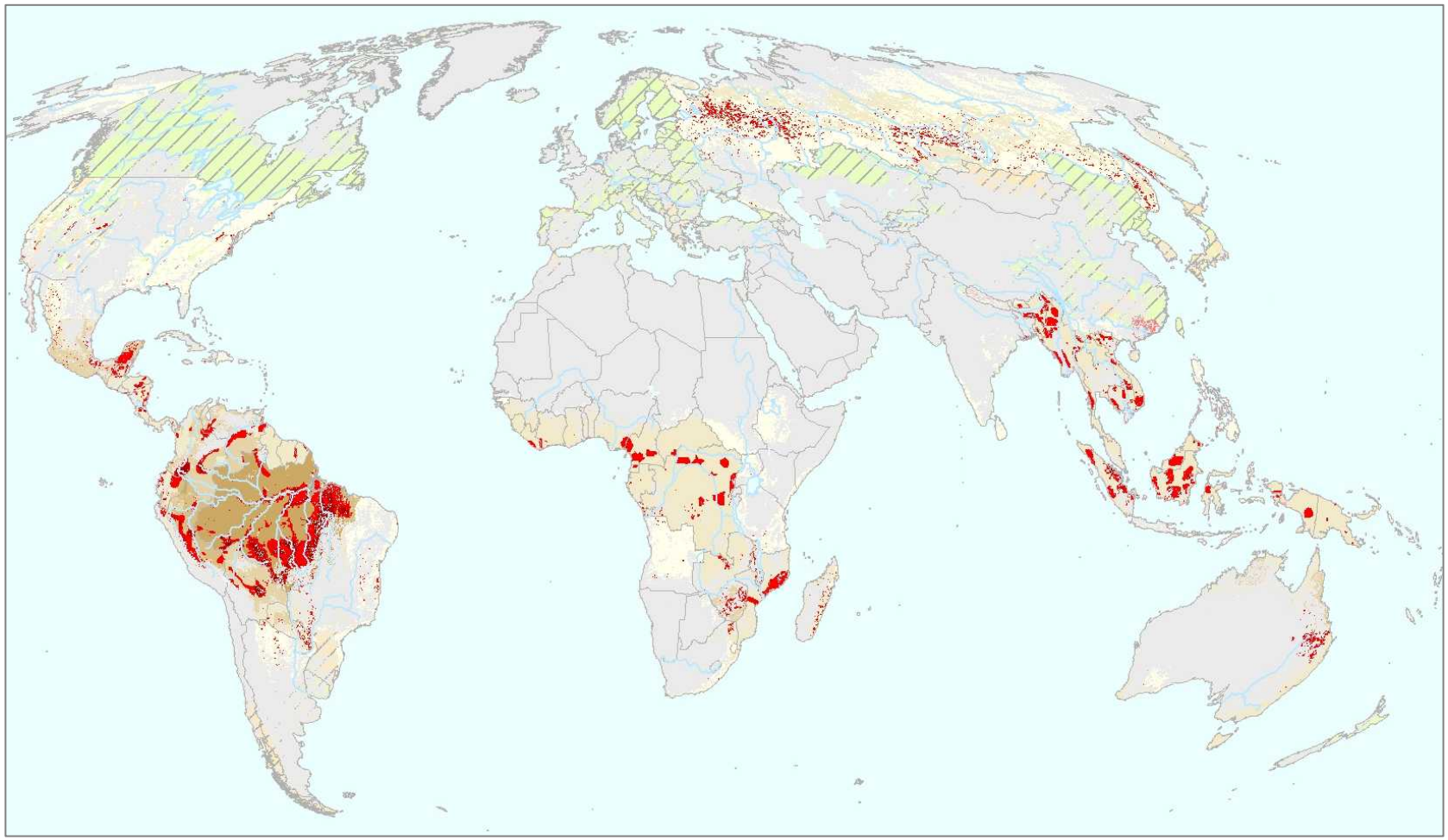
$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow$$
$$HCO_3^- + H^+ \Leftrightarrow CO_3^{2-} + 2H^+$$



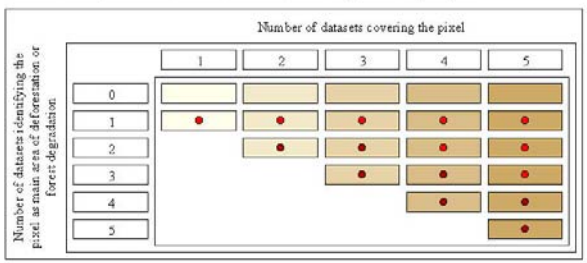
After Turley et al., 2005


QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

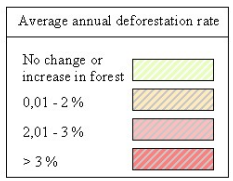
Figure 1: Main areas of deforestation and forest degradation over the last twenty years (1980-2000)



Forest covered by one or more studies based on remote sensing data or expert opinion

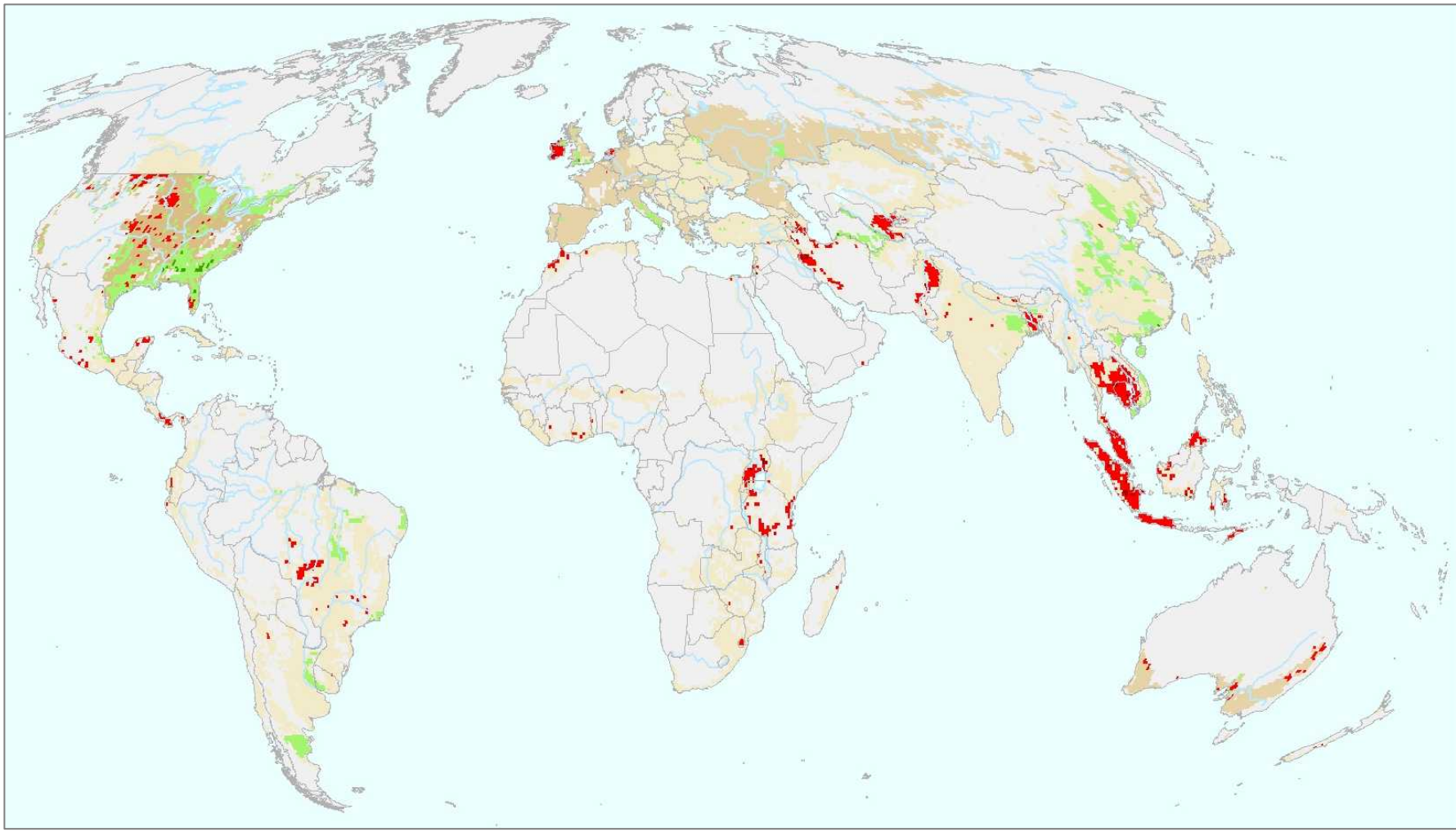


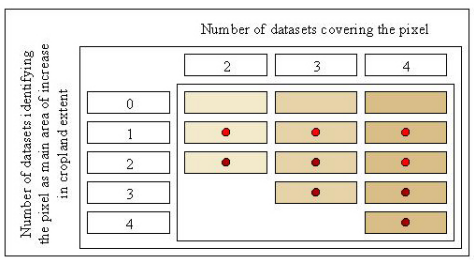
Forest covered only by national statistics

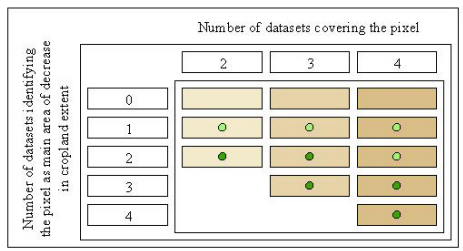


Unforested areas

Figure 3: Main areas of change in cropland extent







Adaptation and Coping

- Because changes occurring now, have both coping to current circumstances and questions about planning for future circumstances to consider
- Requires some knowledge of regional climate changes and environmental consequences
- Requires information on current practices for coping and understanding of factors that control vulnerability
- Requires ability to model effectiveness of adaptation strategies as part of integrated response portfolio

Research Agenda

- Suggests that most important knowledge to get as quickly as possible is information about potential end-points and lag-times
- What are potential magnitudes of important end-points?
- Are there thresholds we must worry about?
- To what degree is there sufficient ecological “buffering” to guard against cascading effects?
- What are the implications for atmospheric greenhouse gas concentrations and therefore emissions and mitigation costs?