Ch 9: Impacts of Climate Change

March 30 & April 6

TERMS

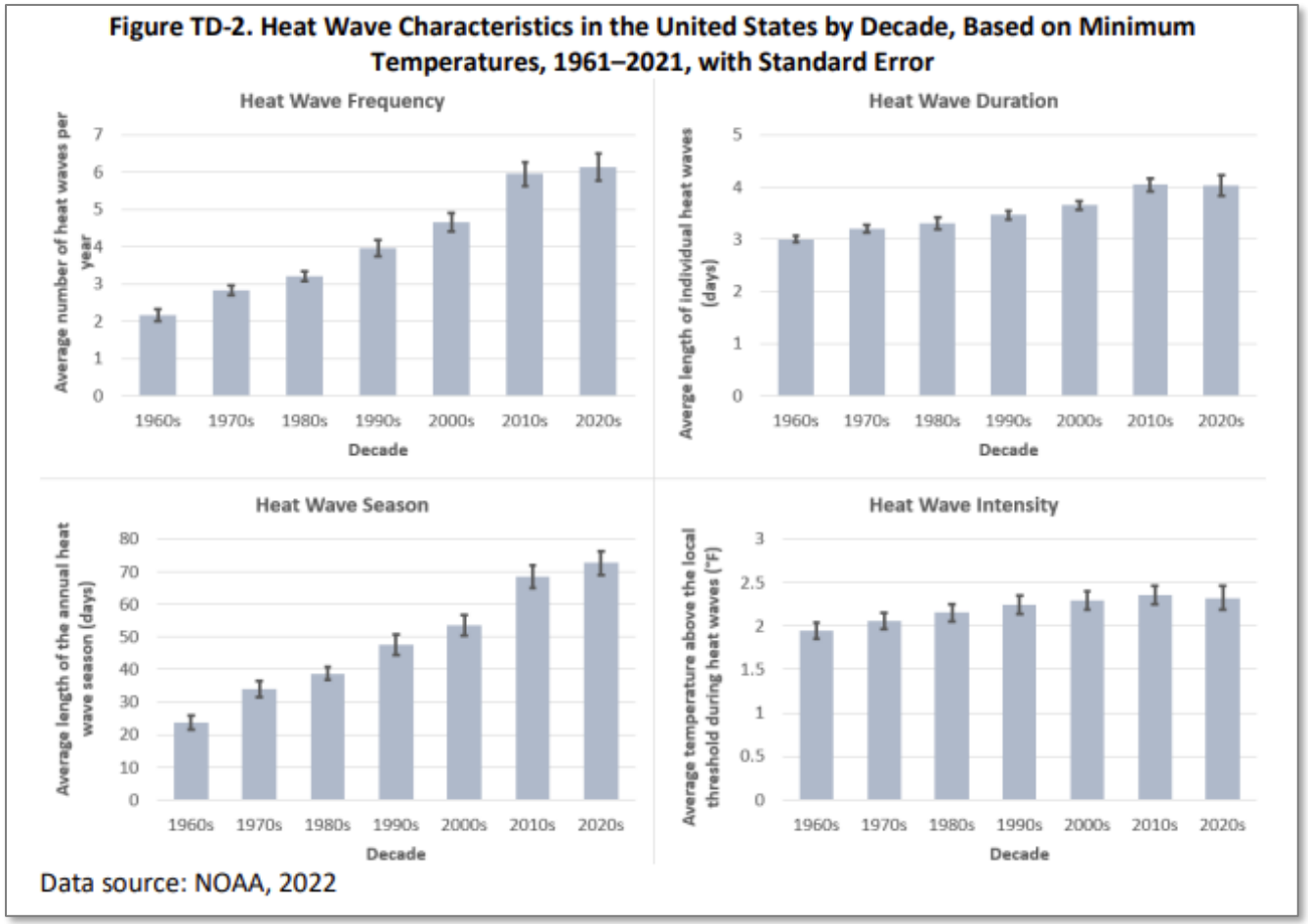
Abrupt climate changes
Ecosystem services
Extreme-event attribution
Global climate model (GCM)
Parameterizations
Storm surge

9.2.6 Attribution Science

After each extreme weather event we wonder, “Did climate change cause this?”
In literal sense, answer almost always “no.”

- Climate Change Is Never the Sole Cause of Extreme Events (e.g., tropical cyclones, heat waves, droughts, wildfires).
- Short-term weather variability, including extreme events, is always to be expected

However, climate change can make these events more intense or more common.



Source: https://www.epa.gov/sites/default/files/2021-04/documents/heat-waves_td.pdf

9.2.6 Attribution Science

Extreme-event Attribution: new field of science over past two decades that provides capability to quantify climate's role – three lines of evidence:

(1) With many observations, statistical analysis can use trends to determine likelihood that an extreme event occurring today could have occurred prior to human-induced warming.

(2) GCM experiments can simulate Earth as (a) real world with humans and (b) imaginary world without humans.

(3) Physical understanding suggests heatwaves during a warmer Earth will likely have increased frequency and intensity.

- Attribution far less confident when it comes to brief and localized events like tornadoes.
- Conclusions of attribution usually specified one of two ways: (1) fractional contribution of climate change toward event, or (2) in terms of probability of event occurring.

9.3 Impacts of These Changes

Climate change will bring certain impacts (e.g., increasing T), and potential ones (e.g., more intense tropical cyclones).

Impacts will change Earth.

- do we wish to stop human-induced climate change, or
- do we view impacts as side effect of humanity?

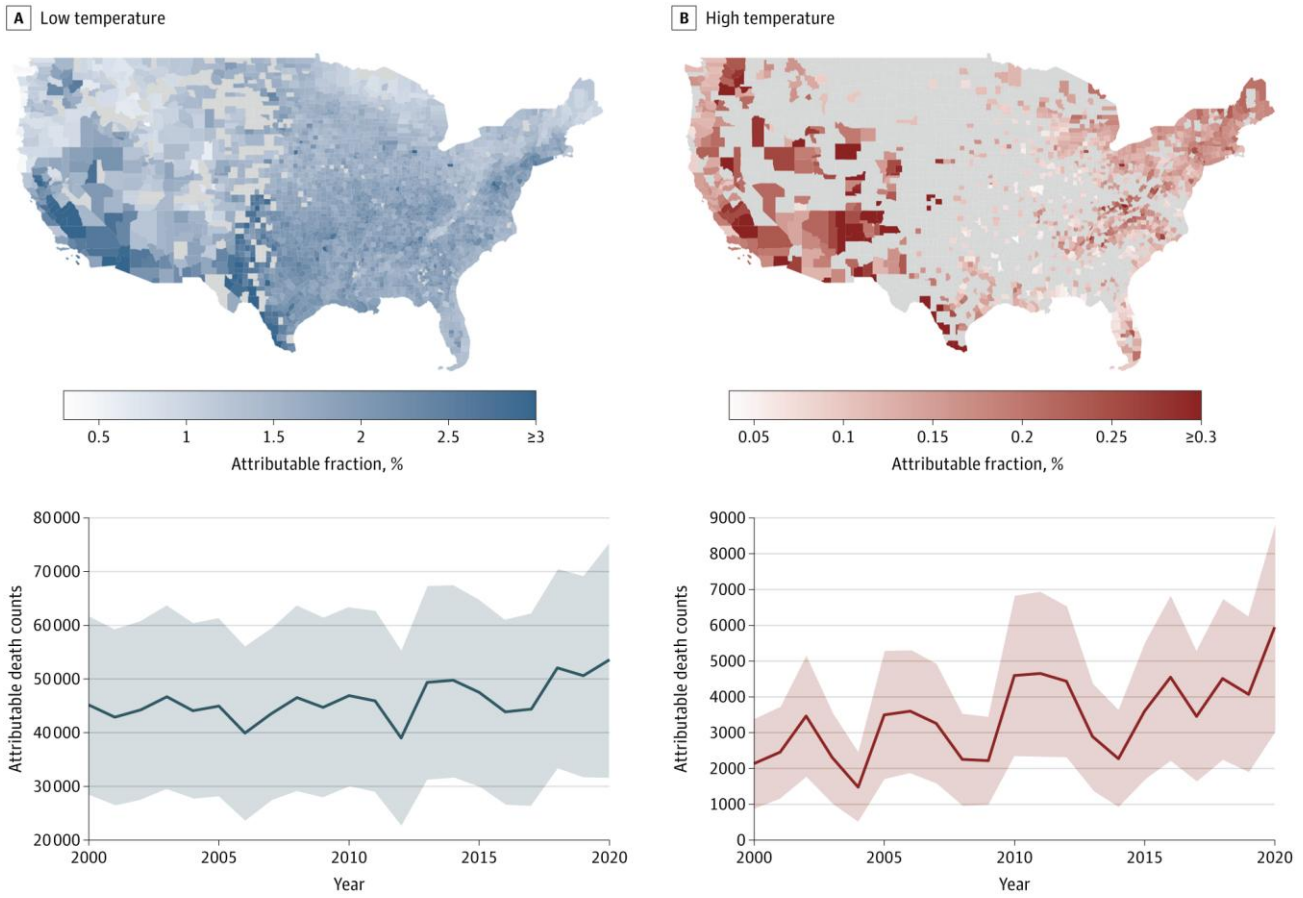


Figure 3. Spatial and Temporal Patterns of All-Cause Mortality Attributable to Low and High Temperatures

Chu, L., Dubrow, R., & Chen, K. (2025). Heat-and cold-related mortality burden in the US from 2000 to 2020. *JAMA Network Open*, *8*(11), e2542269.

9.3 Impacts of These Changes

9.3.1. Non-linearity of Climate Impacts

As climate warms for individuals, damages generally do not get worse slowly over a linear, long-term trend.

Rather damages individuals experience strongly non-linear, meaning do not worsen in gradual fashion - things fine until they are not.

Takeaway: climate change affects individuals after threshold passed.

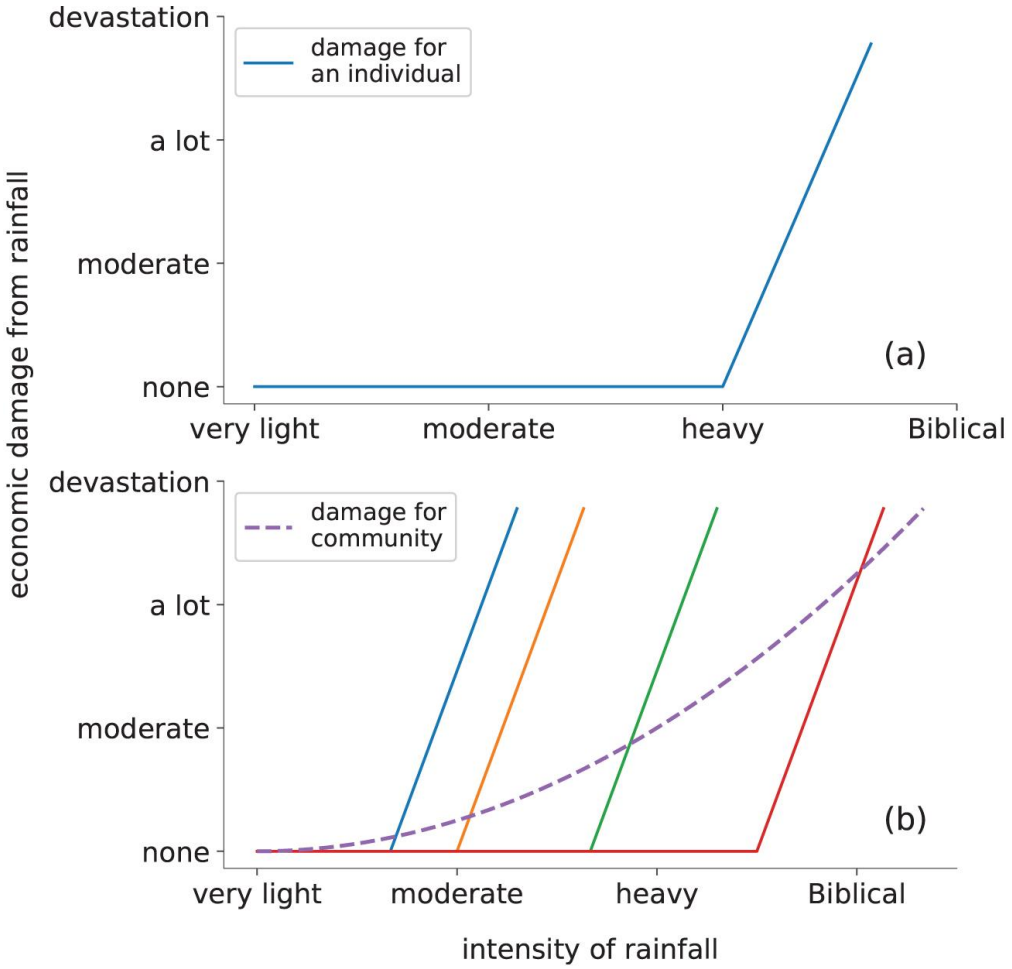


Fig. 9.4: (a) Schematic showing non-linear impact of increasingly intense rainfall for an individual. Increases in rainfall intensity have little impact until they cross threshold of resilience; increases beyond that produce rapidly increasing damage. (b) Schematic showing non-linear impacts on several individuals with different threshold in community (solid lines), as well as damage function for entire community (dashed line).

9.3 Impacts of These Changes

9.3.1. Non-linearity of Climate Impacts

- Climate change worsened rainfall events for decades, but not until 2015 that rainfall exceeded threshold for this individual house.
- In 2014, owners may not have considered climate change a big deal.
- Some houses more vulnerable than others to heavy rainfall events.

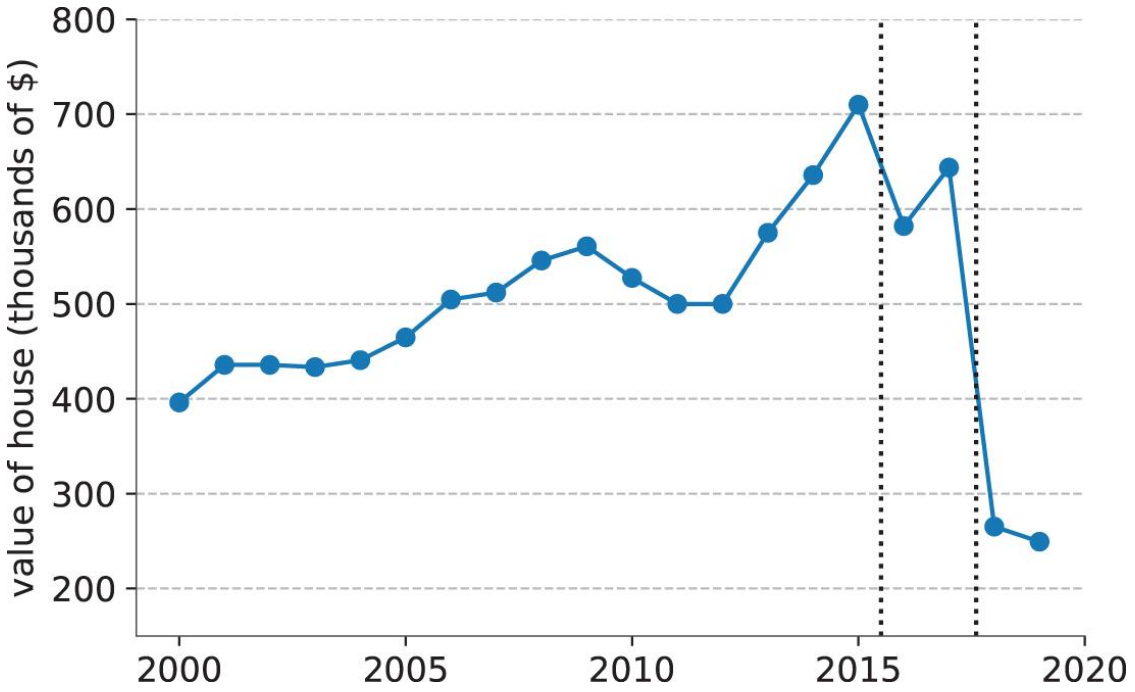


Fig. 9.5: Property value for house in Meyerland section of Houston, TX. Dotted lines indicate dates of two massive flood events that inundated the house.

9.3 Impacts of These Changes

9.3.1. Non-linearity of Climate Impacts

- Vulnerability of individual house likely differs from community average, though community decisions usually made based on community average.
- Community average also non-linear.
- Climate impacts can be socially destabilizing (e.g., property taxes assessed based on value of property).
- If flooding lowers property taxes, that means fewer tax $ for schools, fire departments, hospitals, roads, etc.

Aerial view of 1993 flood looking south (courtesy USGS). Source: https://water.noaa.gov/gauges/jffm7

9.3.1. Non-linearity of Climate Impacts

Social decay leads to people leaving, which lowers property taxes even more, creating positive feedback.

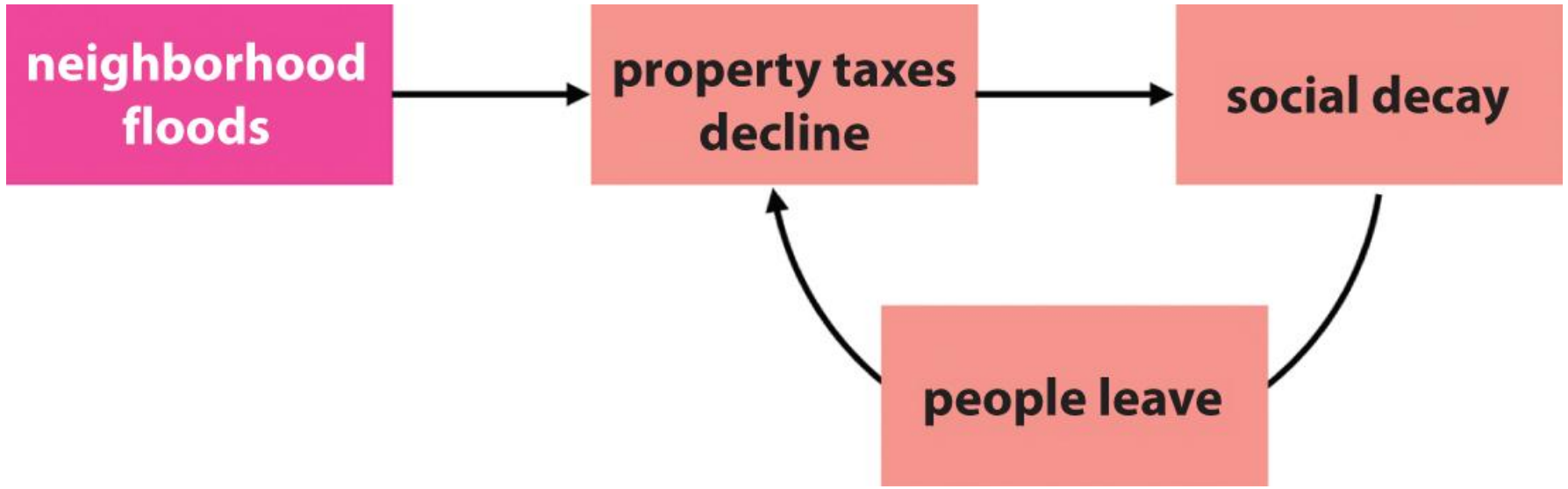


Fig. 9.6: Feedback loop, initiated by flooding, leading to disintegration of neighborhood.

9.3.2 Adaptation

- As climate warms, humans can and will adapt, but by varying amounts.
- On individual scale, neighborhood around **Fig. 9.5** being rebuilt few meters higher off ground.
- On community scale, Houston and New York considering ocean barriers to protect from sea-level rise and storm surge - would cost tens of billions $.
- Ultimately, we all pay: (1) when home floods, (2) with tax dollars as community builds new infrastructure, (3) when repairing existing infrastructure, or (4) with higher insurance premiums.
- If we choose not to spend on adaptation today, then we will spend more on fixing damages later.
- No low-cost option exists to deal with climate impacts - we are already seeing expensive impacts from ~1 K warming.

9.3.3. Unmanaged Systems

Many impacts on unmanaged systems will be harder to deal with (e.g., ocean acidification).

~1 billion people rely on ocean as primary source of protein - *if protein amount decreases there are no simple adaptations*.

At species level, warming already driving some species to extinction (e.g., predicted ~40 % decrease in lizard populations by 2080).
In this specific case, local T at specific time of yr matters.

Interspecies relationships means loss of one will affect entire ecosystem - unintended consequences.

Warming T may put many species or even entire ecosystems at increased risk.

9.3 Impacts of These Changes

9.3.3. Unmanaged Systems

Some species will adapt better than others.

Species will also contend with human interventions such as land-use change, barriers, and intentional or inadvertent transport.

Bottom line: (1) some ecosystems will evolve with new dependencies between species, but (2) some ecosystems may be lost entirely.

If a turtle's eggs incubate <81.86 °F, the turtle hatchlings will be male.

Otherwise >87.86° F, the hatchlings will be female.

9.3.4 Impacts That Are Already Occurring

- Flooding from Hurricane Harvey in 2017 cost communities on US Gulf Coast ~$125 billion in damages - Harvey not caused by climate change, but increased Harvey's rainfall by ~15 %.
- CA fire season in 2018 cost ~$148.5 billion.
- Miami Beach, FL spending ~$500 million to elevate streets and install pumps to deal with rising sea level and higher storm surges.
- Venice, Italy spent ~$6.2 billion over several decades to build barriers to deal with rising sea level.
- Heat-related deaths ~300,000 in 2018.
- Heat-related reduction in economic productivity.

9.4 Abrupt Climate Changes

Changes in T, precipitation patterns, sea level, etc. often occur as steady changes in climate system:

- *Gradual on human time scale, though fast on geologic time scale.*

Abrupt Climate Change = sudden and significant shift in some aspect of climate on human time scale.

Concern climate may <u>not</u> warm smoothly:

- *Large shifts could occur on order of decades.*
- *~12,000 yr ago, Earth emerged from last ice age, but T suddenly plunged creating period known as the Younger Dryas:*

  Possibly due to massive release of freshwater into N. Atlantic from melting glaciers.

9.4 Abrupt Climate Changes

Abrupt changes do happen and must be considered:

1) Rapid shutdown of Gulf Stream, similar to Younger Dryas event, would bring abrupt climate change.
2) Rapid disintegration of W. Antarctic or Greenland ice sheets would increase sea level abruptly.
3) Rapid dieback of Amazon rainforest would have abrupt ecological and socioeconomic damage.
4) Rapid thawing of permafrost and methane hydrates would abruptly release huge amounts of CO_2 and CH_4 into atmosphere (Carbon-cycle feedback).
5) Rapid shift in timing and magnitude of Indian monsoon would abruptly change seasonal rainfall, affecting billions of people.

9.4 Abrupt Climate Changes

Abrupt changes do happen and must be considered:

Most experts view probability low, but not 0 % over this century:

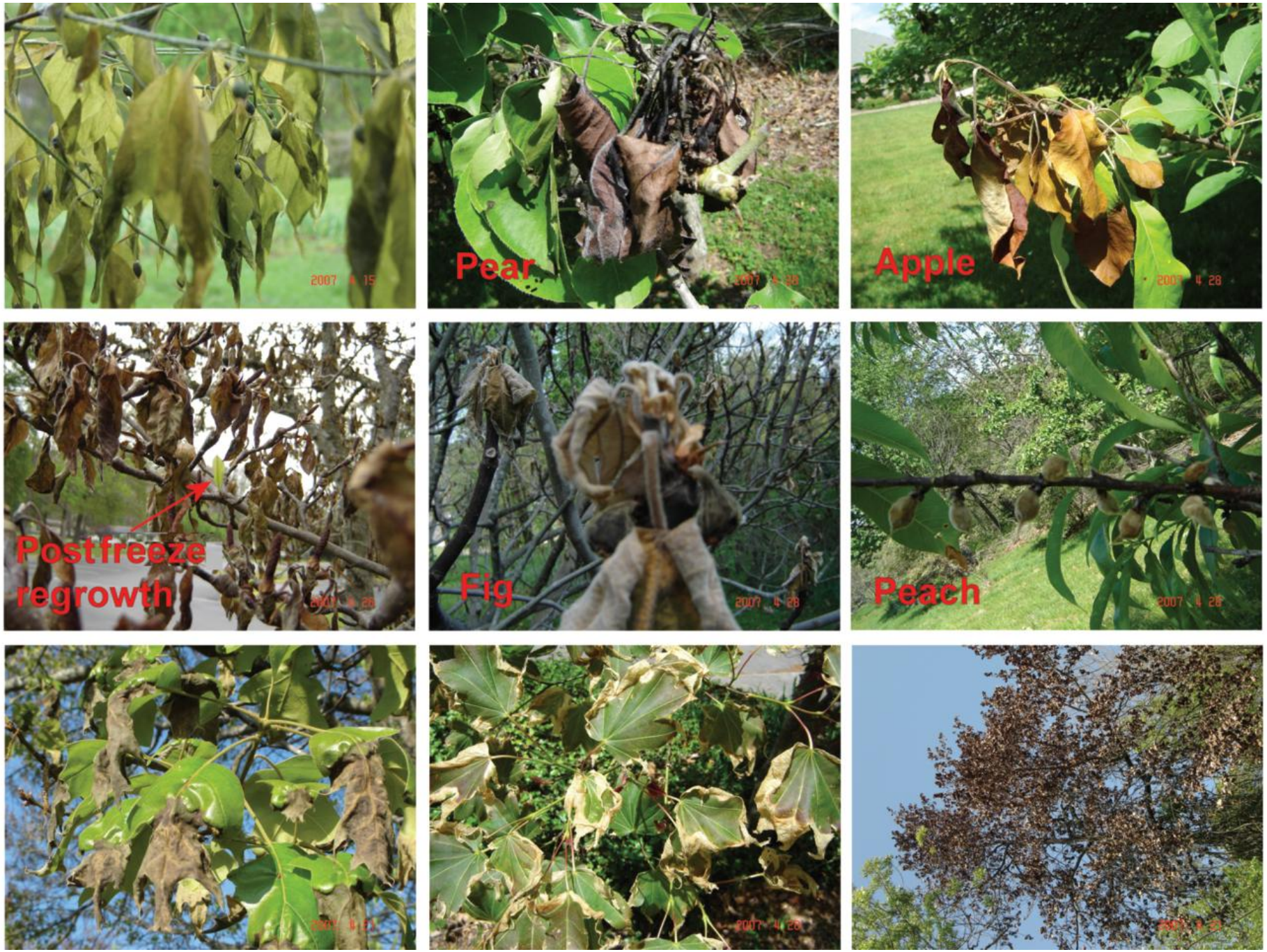
GCMs do not predict abrupt climate change.

Low-risk, high-consequence events pose challenges to society.

Human tendency to ignore risk until after event occurs (e.g., building dam after flood).

If abrupt change takes place, it will be difficult, if not impossible, to manage impacts.

Sample photographs showing different degrees of freeze damage to leaves and fruits of natural and horticultural species in Oak Ridge, Tennessee.
(Gu et al. 2007)



9.5 Putting It Together

Climate change already making extreme events more severe, despite only warming ~1 K since 1750.

GCMs predict additional warming of ~1.0 - 4.5 K by 2100.

When people say that solving climate change will cost us $ and hurt economy, know that not solving climate change already costing us $ and hurting economy.

We must balance costs of action vs. costs of inaction.

Tempting to assume “well, we’ll deal with it.”

How well will we deal with it?
In what shape will we emerge?
How much will it cost us in lives and damages?

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