Climate Change and Impacts to Idaho January 24, 2020

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The topic of climate change and its impacts is critically important to the people and economy of Idaho, and it is now being discussed by the public and state legislature. Decisions about policy should be supported by the best available information, but the science about this topic was not represented by a policy brief recently released by the Heartland Institute. Here we summarize the scientific understanding of climate change and its impacts in Idaho, the Northwest, and globally. Our credentials include teaching and doing research on climate change and impacts, and we have been contributing authors to multiple climate change assessments. We are representing ourselves as individuals with expertise in the topic of climate change; our views are our own and do not represent those of our current or former employers.

The sources used here are studies published in peer-reviewed scientific journals and summarized by local, national, and international scientific syntheses and reviews, in contrast to blogs, web sites, newspapers, or similar types of publications that are not independently reviewed by experts. (Appendix A clarifies or corrects statements made in the Heartland Institute policy brief.)

It is well established that the climate has changed in the last 150 years. Temperatures have increased during this period, both globally and in Idaho, with the warmest years occurring in the last two decades. Other components of the climate system, including those in Idaho and the Northwest, have provided additional evidence consistent with this warming, including glaciers and sea ice melt, reduced snowpack and earlier snow melt, increases in atmospheric water vapor, and rising sea level.

Using multiple lines of evidence, the cause of this climate change has been attributed with high confidence to human activities that result in greenhouse gas emissions. With continued emissions of greenhouse gases in the future, scientific projections of future climate indicate additional warming, reductions in ice and snow, sea level rise, ocean acidification, and other climate-driven responses.

Historical and projected climate change will result in both positive and negative effects on human and natural systems. (Appendix B describes significant impacts that have occurred in Idaho or are expected to occur in the future.) Some studies indicate that crop yields will increase in response to future warming, although other studies identify factors such as pests and increased moisture stress that will offset those increases. Cold-caused human mortalities are expected decline with warming.

A large number of impacts that negatively affect existing human and natural systems have been identified, and many occur in Idaho. Climate change is expected to cause shifts in vegetation types in Idaho, including losses of forests and expansion of deserts. Wildfires have increased in recent decades and are projected to continue in the future, with a range of consequences: increased costs of fire suppression, loss of life and structures, smoke inhalation from near and far fires that causes respiratory disease, and threats to timber and recreation industries. Tree die-offs from drought, insects, and disease have occurred recently in response to warmer and drier conditions, and these disturbances are expected to continue. Warming has reduced snowpack and caused earlier snow melt, and these effects will accelerate in the future, creating challenges for water uses in Idaho that include hydropower, irrigation, and municipal uses. The shrinking snow season also affects snow sports and associated industries, including tourism. Lower summer streamflow raises water temperatures that stress local fish species, potentially increasing the number and frequency of fisheries closures. More extremely hot days during summer will reduce worker productivity and increase heat-related human mortality.

The best available science indicates that climate change is real, is happening now, is caused by human activities, and has serious consequences for Idaho's landscapes, economy, and people. Future climate change and its impacts can be reduced if greenhouse gas emissions decrease, however.

Appendix A. Clarifications and corrections to Heartland Institute Policy Brief titled "Climate Change and Idaho: A Scientific Assessment", published in September 2019

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Table of contents: Statements in the Heartland Institute Policy Brief that are clarified/corrected in this document

The positions expressed in this document are our own and do not represent the University of Idaho or other past employers.

1. *Heartland statement: "Weather and climate data show climate change has a minimal impact on Idaho" (Summary, P 1) and "Idaho temperatures have warmed only modestly during recent decades" (Summary, P 1) and the "…newest, most reliable temperature stations…show virtually no warming since their inception"* (P 2, P 7, and Figures 2, 3, 4)

BOTTOM LINE: Idaho has warmed over the last 100+ years, with the warmest years occurring in the last two decades, in contrast to what is reported in the Heartland Institute Policy Brief.

DETAILS: Over the last 100-150 years, temperature has increased in Idaho and warming appears to be accelerating in the most recent decades.

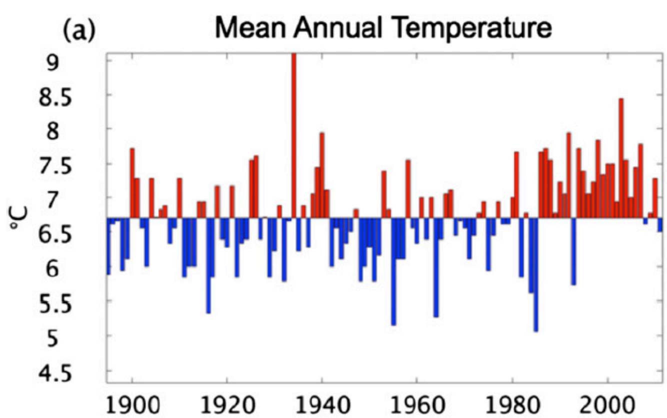

Figure 5 from Klos et al. (2015) showing mean annual temperature for the 29 US Historical Climatology Network stations (the highest-quality long-term weather stations) in Idaho. The last two decades were the warmest on record (1894–2010). The recent warming rate was 0.24 ºC/decade (0.43 ºC/decade).

Phrases such as "minimal impact" and "warmed only modestly" can mean different things to different people. See below for discussion of what impacts have occurred as an indicator of importance.

Weather stations in NOAA's Climate Reference Network are designed to avoid biases and produce high-quality climate information suitable for establishing trends. Station data are available from the 2000s onward, and thus this data set only has 10-20 years of observations. This period of time is too short to establish changes in climate, which by definition is the long-term (30-year) average of weather.

2. *Heartland statement: “Idaho is experiencing a long-term gradual increase in precipitation, alleviating any fears of a long-term increase in drought.”* (Summary, P 1)

BOTTOM LINE: Climate projections indicate that droughts will continue and worsen as a result of future warming, and impacts can be significant, in contrast to statements in the Heartland Institute Policy Brief.

DETAILS: Drought is caused by both reduced precipitation and higher temperature. In Idaho, both temperature and precipitation have increased over the 20th century, and a drought metric that combines the two (climatic water deficit) indicates reduced drought stress in northern Idaho and slightly increased stress in southern Idaho over 1920-2012 (Abatzoglou et al. 2014). In more recent decades, deficits have increased, indicating drier, more stressful conditions (Abatzoglou et al. 2014).

Warming even with no change in precipitation results in hotter droughts that are more stressful to vegetation. One visible consequence of hotter droughts is that they have been identified as responsible in part for extensive tree die-offs globally, including in the western US and Idaho (Allen et al. 2010).

Climate model projections indicate continued warming in the coming decades in the Northwest in response to increasing greenhouse gas concentrations (Kunke et al. 2013). Regionally, total annual precipitation is expected to increase slightly (although the statistical confidence of this is low), but importantly, summer (growing season) precipitation is projected to decline when averaged across projections (see below figure) (Kunke et al. 2013, USGCRP 2017). As a result of this warming and summer drying, drought metrics indicate drier conditions in the future in Idaho and the Northwest (Dai 2013).

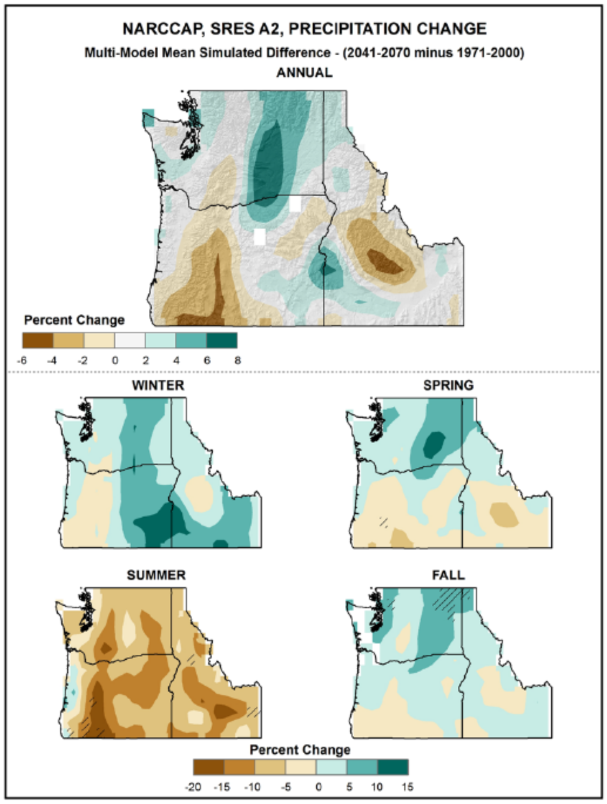

Figure 21 from Kunke et al. (2013) (a NOAA technical report) showing projections of annual and seasonal precipitation.

3. *Heartland statement: "What little warming has occurred has largely been beneficial for Idaho, with crop production setting new records virtually every year."* (Summary, P 1)

BOTTOM LINE: Studies of long-term trends of crop yields are needed to establish the influence of climate change, not a comparison of individual years as presented in the Heartland Institute Policy Brief. A wide range of impacts have occurred in response to climate change or are expected to occur in the coming decades; many are viewed as negative impacts to Idahoans.

DETAILS: Human and natural systems are driven by multiple factors. Isolating the contribution of climate change requires consideration of all relevant drivers and is therefore often challenging. Increasing crop production may be caused by a number of factors, including warming but also improved fertilization, irrigation, crop varieties, and economic factors, among others.

Climate change may have been beneficial for crops by extending the growing season, providing better (warmer) conditions for growth, and increasing atmospheric CO_2 that allows for more growth. Scientific studies of long-term trends in crops and attribution of any such trends to climate in Idaho are needed to establish this understanding, not comparisons of yields in individual years. A study of winter wheat yields over the last 30 years in the Columbia River Basin reported that moisture conditions (influenced by temperature as well as precipitation) had a major influence on yields and that years with warmer conditions during the late stages of wheat development resulted in lower yields (Feng et al. 2017).

Projections indicate that climate change may be beneficial for some crops such as wheat as a result of increases in precipitation and carbon fertilization, but higher temperatures can be detrimental (Gowda et al. 2018). Furthermore, climate change is also expected to increase outbreaks of agricultural weeds, pathogens, and insects (Gowda et al. 2018) that will reduce yields and increase costs of pest management.

See separate document for more details about impacts in Idaho.

4. *Heartland statement: "Idaho already emits few carbon dioxide emissions, with almost no impact on global temperature."* (Summary, P 1)

Emissions of greenhouse gases, including carbon dioxide, have been responsible in large part for recent climate change (IPCC 2014). Although Idaho itself may have relatively small emissions of greenhouse gases, it nonetheless will experience impacts as a result of global emissions and climate change. Local climate change and impacts are driven by global, not local, emissions because greenhouse gases stay in the atmosphere for decades and thus are well mixed throughout the atmosphere. Reducing greenhouse gas emissions in Idaho and everywhere else is needed if society's goals are to reduce future climate change and its impacts in Idaho and elsewhere.

5. *Heartland statement: "Extreme weather events are becoming less frequent."* (P 4)

Extreme precipitation events have increased nationally and in the Northwest since 1901 (USGCRP 2017). Model projections indicate increasing extreme precipitation events in the Northwest in future decades (USGCRP 2017). Warming is projected to lead to more frequent and intense heatwaves in the region (USGCRP 2017), and will cause more frequent and severe droughts (USGCRP 2017).

6. *Heartland statement: "The pace of recent warming continues to be much slower than U.N. climate model predictions."* (P 4)

Continued text in Heartland Institute brief: *"In 1990, the U.N. Intergovernmental Panel on Climate Change (IPCC) predicted global temperature would rise by 0.3 degrees C per decade.[18] However, empirical temperature data covering the three decades following 1990 show the average global temperature rise has been only about 0.13 degrees C per decade, less than half the pace IPCC predicted.[19] As a result, IPCC lowered its prediction to just two-tenths of a degree C per decade, and likely will need to lower it again.[20]"*

BOTTOM LINE: Both models and observations indicate warming since 1990. Early models did not include some mechanisms responsible for recent temperature patterns, such as the responses of ocean heat content, or used atmospheric input data that did not represent what actually happened, causing differences with the observed rate of warming in recent years. More importantly, results from climate models for the last 100 years match observations well, giving confidence about their ability to project future climate.

DETAILS: Climate models are developed by simulating important components of the climate (atmosphere, land, ocean) using knowledge about physics and biology. Models have to accommodate a range of spatial and temporal scales, and that complexity is challenging. Results from climate models have been evaluated in multiple ways, such as by testing predictions of individual components against observation. Importantly, climate model results for 20th century temperatures have replicated the warming during this period well, increasing our confidence in future projections (see below figure) (IPCC 2014).

Comparisons of early model projections (beginning as early as the 1970s) with observations indicated agreement within the confidence intervals of the observations, and differences decreased when differences in greenhouse gases in observations and used as input were accounted for (Hausfather et al. 2019). In more recent years, global warming slowed because of multiple factors, but both models and observations agree on the general pattern of warming (Medhaug et al. 2017).

More relevant is the implied question of the ability of climate models to accurately project the future climate. Longer-term general agreement between models and observations during the last century (below figure) increases confidence in model projections (IPCC 2014).

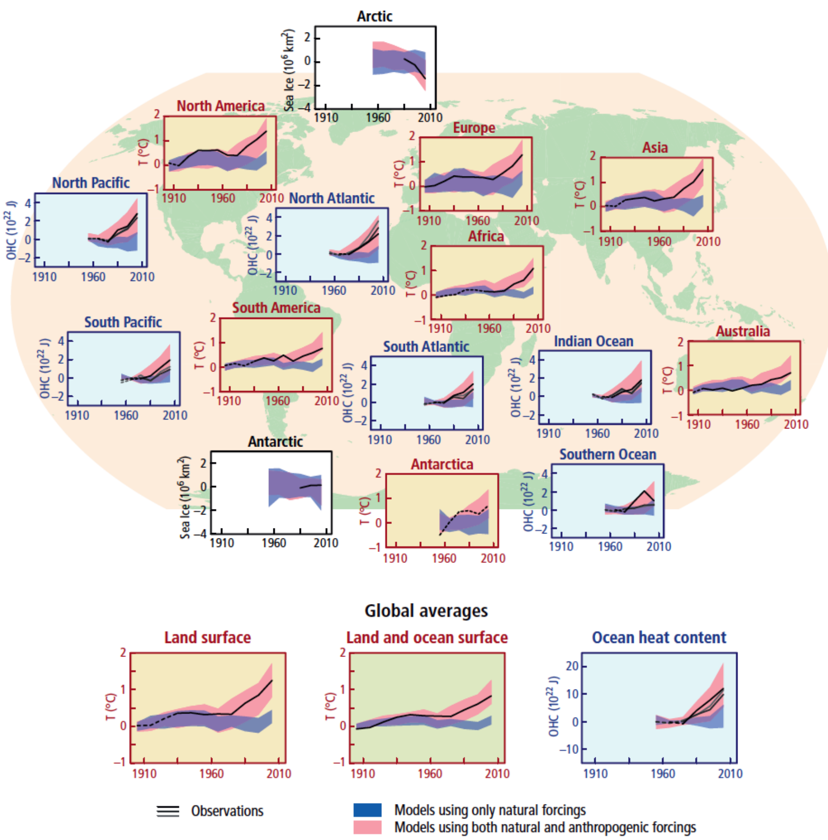

Figure 1.10 from the 2014 IPCC Synthesis Report (IPCC 2014) showing observations of climate components during the last 100 years and climate model results with and without human activities that cause climate change ("anthropogenic forcings"). Three important points: 1) observations (black lines) indicate warming and associated responses in the climate system; 2) climate model results that include all factors (both "natural forcings" and "anthropogenic forcings"; red bands) were consistent with observations, increasing confidence in the models' ability to simulate climate; and 3) the model results without human activities do not replicate the observations, providing evidence that climate change has been caused by human activities.

7. *Heartland statement: "The reality that thermometer readings have shown no dramatic climate change is masked in part by government gatekeepers who have adjusted raw data to give the appearance of more recent warming.[23] (See Figure 1.)"* (P 5)

BOTTOM LINE: Scientists have developed data sets that correct for known issues that adversely affect temperature trends; trends calculated from the raw data include these biases and so are incorrect. Moreover, multiple climate metrics have indicated warming since 1900, corroborating thermometer observations.

DETAILS: The US Historical Climatology Network (HCN) data set was developed from a subset of weather stations to assess long-term trends in climate (Menne et al. 2009). In creating this high-quality data set, climate scientists recognized that temperatures recorded over the last 150 years may have been adversely affected by several issues (changing observation time of day, changing in station location, etc.). Scientists therefore developed methods for applying adjustments to account for these biases. Without these corrections, an analysis of raw data would produce invalid trends because these trends would include known biases and problems.

Scientists have also found a warming trend by incorporating climate observations other than land temperatures into a climate model that then calculates temperature, and these results agreed well with HCN-based trends (Compo et al. 2013). Another study analyzed temperature records from global weather stations with the intention of examining the adjustments used in the HCN data set and found results that are similar to previous studies (Rohde et al. 2013).

More broadly, multiple components of the climate system have responded in ways that are consistent with observations of land-based warming, including snow and ice melt, sea level rise, increasing water vapor, and ocean warming (IPCC 2014).

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Appendix B. Summary of Impacts of Recent and Future Climate Change in Idaho

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This document is organized by impact or sector.

Sources

- information in this report is drawn from the peer-reviewed literature and summaries/syntheses/reviews of climate change in local, national, and international assessment reports (see end of document)
- Idaho examples are provided when available; some findings may be based on regional (US Northwest) studies of impacts; in cases where local or regional studies are not available, findings are based on the best scientific understanding of climate influences

Impacts

- In the Northwest, 2015 was a year that may be a good example of what are likely to become normal conditions in the future: hotter conditions (along with drier conditions, which are not projected in the future during winter and spring) led to severely reduced snowpack (Sproles et al. 2017); the warmer and drier conditions led to impacts to irrigation, agriculture, snow recreation, hydropower, wildfires, and fish kills and extensive economic impacts from crop loss (Mote et al. 2014). Climate models project warming and summer drying that is expected to result in similar years in the future.

- water
  - snowpack
    - late 20th century warming has caused declines in snowpack and earlier snowpack melt across the western US, including Idaho (Mote et al. 2018)
    - Idaho streamflow peaks associated with snowmelt have come earlier in recent decade and have been reduced (Mote et al. 2014, Klos et al. 2015)
  - temperature
    - reduced streamflow, especially in summer, causes water warming
      - stream temperature for the North Fork Clearwater River has increased by about 1 deg C (1.5 deg F) since 1970 (Klos et al. 2015)
  - quantity
    - earlier peak flows (Mote et al. 2014, Klos et al. 2015)
      - dam operations: hydropower, irrigation
    - reduced summer flows and higher stream temperatures impact aquatic ecosystems, including fish
  - quality
    - increased potential for harmful algal blooms in freshwater as a result of warming water (Mote et al. 2014)

- wildfires

  - Idaho fire seasons have lengthened by 47 days in the last 25 years (Klos et al. 2015)
  - a warmer and drier atmosphere in the last 30 years has led to greater fuel aridity and increase in area burned in the western US (Abatzoglou and Williams 2016)
  - climate projections are expected to increase burned area in Idaho's forests (Littell et al. 2018)
  - impacts
    - damage to structures
    - injury/death from fires
    - smoke
      - long-distance effect
      - health issues, recreational impacts
    - costs of suppression
    - recreational lands closures after burns
    - soil degradation and siltation of streams (Helvey 1980, Helvey et al. 1985)

- recreation
  - fishing
    - closures due to fish die-offs or poor returns as a result of lower streamflow, higher stream temperatures that stress fish, or warming ocean conditions that affect migrating fish species
  - snow sports
    - snow season lengths in Idaho ski areas are projected to decrease by 50% or more by 2050 (Wobus et al. 2017)

- health
  - smoke from wildfires and extreme heat events have led unhealthy conditions and increases in respiratory illness in the region, and these health concerns are expected to increase in the future from climate change (Mote et al. 2014)
  - air quality from projected increases in ozone and pollen will increase adverse respiratory conditions (Mote et al. 2014)
  - heat-related deaths are expected to increase in the region (Mote et al. 2014); decreases in cold-related mortality in Idaho are projected to exceed these increases, leading to a reduction in overall climate-related human mortality (Hsiang et al. 2017)

- agriculture and food
  - productivity
    - projections of improved wheat yields from CO_2 fertilization and warming (Karimi et al. 2018, Stöckle et al. 2018)
  - projected increases in crop production by the end of this century (study considered wheat, soybeans, maize, cotton only) in Idaho (Hsiang et al. 2017)
  - shifting crop locations
    - future warming may lead to expanded area of conditions suitable for growing some perennial crops (Parker and Abatzoglou 2016)

    - insect, disease, and weed pests may increase in response to climate change, thereby offsetting some yield increases (Stöckle et al. 2018)
    - fisheries (see above)
    - livestock production
        - forage may increase in Idaho with future climate change (Reed et al. 1999, Hufkens et al. 2016)
        - longer grazing season and shorter period of winter feeding
        - hotter summers are expected to lead to greater heat stress of livestock, which reduces productivity (St-Pierre et al. 2003)

- forestry
    - tree species adapted to lower elevation, moisture-limited landscapes (such as Douglas-fir or ponderosa pine) will be stressed more by warming (Littell et al. 2010), and in Idaho warming may lead to shifts to non-forest vegetation types in these locations that are adapted to drier conditions (Rehfeldt et al. 2006)
    - higher elevation spruce and larch may be eliminated from many landscapes as conditions become too warm or dry (Rehfeldt et al. 2006)
    - forest disturbances are expected to increase in Idaho because of warming and summer drying
        - wildfires (see above)
        - drought
        - Idaho has experienced substantial tree mortality from bark beetles (600,000 ha or 1.5 million acres of dead trees in last several decades) (Hicke et al. 2016), and warming and drought have played roles in these outbreaks (Buotte et al. 2017) as well as outbreaks of other forest insects and pathogens (Sturrock et al. 2011, Weed et al. 2013, Kolb et al. 2016); future climate change will lead to more favorable conditions for bark beetle outbreaks (Buotte et al. 2017)

- vegetation
    - projections indicate that southern Idaho will experience expansion of deserts, northern Idaho will lose forests (Rehfeldt et al. 2006)

- animals
    - fish stressed by higher water temperatures
        - locally
        - in Pacific Ocean for important migrating fish species (salmon)

- economic impacts
    - a study of economic damages from future climate change (Hsiang et al. 2017) found that in Idaho, agricultural yields will increase, mortality from cold-related deaths will decrease, energy expenditures will decrease, and damages associated with labor and crime will increase; total economic impacts for Idaho will be beneficial when summed across Idaho as a result of the yield increases and mortality decreases; caveats include incomplete modeling of yields, lack of

adaptation that would reduce damages, lack of inclusion of other important economic costs (e.g., wildfires, health hazards)

Sources of information

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