HUBBARD BROOK ECOSYSTEM STUDY

FACTS ABOUT CLIMATE CHANGE

The Hubbard Brook Experimental Forest is one of the longest running and most comprehensive ecosystem study sites in the world. Established by the USDA Forest Service in 1955, this 7,800-acre research site is located in the White Mountains of New Hampshire.

Meticulous climate and streamflow records have been maintained for more than 60 years as part of the long-term research at this site. These data demonstrate how climate is changing at this northern hardwood forest. This fact sheet shares highlights from the long-term record at Hubbard Brook.

1. Air temperatures have warmed. Average annual air temperatures at Hubbard Brook have varied over the past 60 years from a low of 40°F in 1965 to a high of 47°F in 2012. Despite year to year variations, the overall trend shows that average annual air temperature has warmed by about 2.6°F over the past 60 years. Records from other locations in New Hampshire show the same trend, with average annual temperature increases of 2–3°F over the past century, compared to an average global temperature increase of 1.5°F over the same period. This is consistent with observed trends worldwide for greater warming at higher latitudes.

2. Winters have warmed more than other seasons. Temperature increases have been recorded across all seasons, but winter temperatures have risen the most, with average winter temperatures 3.5°F warmer since 1956. Summer and fall temperatures have warmed by 2.3°F over this period and spring temperatures are up by 2.2°F.

3. Minimum temperatures have warmed more than maximum temperatures. Daily minimum temperatures, which typically occur at night, have risen by an average of 3.1°F, while daily maximum temperatures have risen by 2.3°F since 1956. Increase in winter minimum air temperature is particularly significant with a change of 5°F since 1956. Summer minimums, in contrast, have increased by 2.5°F over the same period.

4. Fewer cold days. Since 1956, there are 10 fewer days per year with a daily maximum air temperature less than 32°F and there are 20 fewer days per year during which the daily minimum is less than 32°F.

5. Precipitation has increased. Annual precipitation has ranged from a low of 36.5 inches in 1964 during the drought of the 1960s to a high of 72.9 inches in 1973. On average, annual precipitation has increased by 12 inches since 1956. Precipitation has not increased uniformly across the year. In general, the increase has been greater in the summer (increase of 6.6 inches), followed by fall (increase of 2.6 inches), spring (increase of 2.1 inches), and winter (increase of 0.66 inches). Other locations in New Hampshire show similar trends over this same period.

6. Heavy precipitation events are increasing. The number of days in a year with heavy precipitation, defined as days with more than 0.75 inches of rain, has ranged from a low of 10 days in 1964 to a high of 33 days in 1973. Since 1956, the number of days in the year with heavy precipitation has increased by 7.5 days. This trend is consistent with observations from other locations across the northeastern United States showing a 70 percent increase in "extremely heavy storms" since the 1950s, as reported in the 2014 National Climate Assessment.

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7. Streamflow has increased. The annual streamflow in the Hubbard Brook reference watershed has ranged from 17 inches in 1964 to 52 inches 1973. On average, annual streamflow has increased by about 14 inches since 1956. This increase is similar to the increase in precipitation (12 inches), indicating that the additional precipitation has been transferred to streams. On average, there are about 7 more high-flow days (streamflow greater than 95th percentile) and 50 fewer low-flow days (streamflow less than 10th percentile) since 1956.

8. Spring runoff has occurred earlier. The timing of spring runoff, measured by "center of volume," is earlier in the year by about 7 days. "Center of volume" refers to the date by which half of the streamflow for a winter–spring period has flowed out of the watershed.

9. Snowpack has decreased. The maximum snow depth at Hubbard Brook has ranged from a high of 54.5 inches in 1969 to a low of 8.6 inches in 2016, and the number of days with snow on the ground has ranged from a high of 161 days in the winter of 1971–1972 to a low of 49 days in the winter of 1994–1995. Since 1956, average snow depth has declined by 12 inches. The number of days with snow on the ground has declined by 24 days. Also, the amount of water held in the snowpack, called the "snow-water equivalent," has declined by 42 percent.

10. Duration of lake ice cover has decreased. Mirror Lake, on the eastern end of Hubbard Brook valley, has one of the longest running ice-cover records in the world, from 1968 to present. Ice cover at Mirror Lake has ranged from 91 days per year in 2015 to 149 days per year in 1968. Since 1968, the number of ice-cover days at Mirror Lake has declined by 25 days. This change is driven by earlier ice-out dates in the spring as opposed to later ice-in dates in the winter. Ice-out is occurring about 14 days earlier and ice-in is occurring about 7 days later now than in the late 1960s.

SUMMARY:

Long-term records from the Hubbard Brook Experimental Forest indicate a shifting climate since the 1950s. This includes increases in and changing patterns of stream flow, and decreases in snow and lake ice cover. Climate models suggest that these changes will continue into the future, with consequences for vegetation and wildlife, erosion and flooding, and impacts on forestry, maple syrup production, tourism and recreation.

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Data sources:

Data referenced in this Fact Sheet compiled from Bailey, A.S., J.L. Campbell, M.B. Green, and L. Rustad. Long-term trends and foundation datasets at Hubbard Brook Experimental Forest, Woodstock, New Hampshire, USA. U.S. Forest Service, General Technical Report, in preparation, last updated on November 30, 2016. Climate data are from Weather Station 1; stream-flow data are from the hydrologic reference catchment Watershed 3; snow data are from snow course 2.

For additional information about Hubbard Brook:

- Holmes, R.T. and G.E. Likens. 2016. *Hubbard Brook: The Story of a Forested Ecosystem.* New Haven: Yale University Press, 271 p.
- Hubbard Brook Ecosystem Study: **http://www.hubbardbrook.org**
- Rustad, L., J. Campbell, J.S. Dukes, T. Huntington, K.F. Lambert, J. Mohan, and N. Rodenhouse. 2012. Changing climate, changing forests: The impacts of climate change on forests of the northeastern United States and Canada. U.S. Forest Service, General Technical Report NRS-99, pp. 1–48.

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