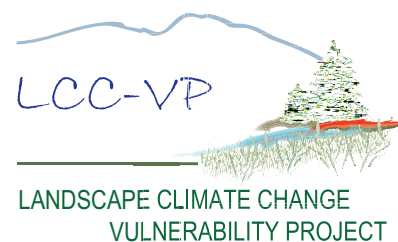


Great Smoky Mountains National Park Climate Change Brief



What We've Seen: Observed Trends in Temperature and Precipitation

Great Smoky Mountains National Park contains some of the highest elevation terrain in the south-east, giving the park some of the coolest annual temperatures in the region and some of the highest levels of precipitation in the U.S. This climatic diversity supports a wide range of species and ecosystems, including a global hotspot of salamander diversity, and is a critical part of the visitor experience.

Unlike other parts of the U.S., the southeast has not shown significant warming trends over the past century (Capparelli et al. 2013). Minor cooling of 0.4°C calculated from gridded climate surfaces for the Park and surrounding area over the last century (Figure 1a) is consistent with this broader regional pattern.

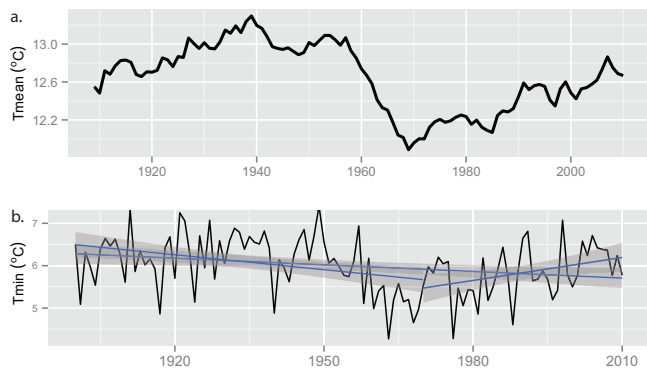


Figure 1. (a) Ten year rolling mean shows average temperatures fluctuating on a multidecadal time scale in GRSM. **(b)** Linear trend tests show minimum annual temperature decreased by $1.2^{\circ}\text{C}/\text{century}$ in the first half of the 1900's followed by an increase of $1.8^{\circ}\text{C}/\text{century}$ in the past few decades resulting in an overall decrease of $0.5^{\circ}\text{C}/\text{century}$ (calculated by the authors from PRISM data (Daly et al. 1994)).

Temperature anomalies, defined as departures from a long term mean, show multi-decadal fluctuations on the order of 1°C , revealing the influence of low frequency changes in sea surface pressure in the Western and North Atlantic Ocean (Anchukaitis 2006).

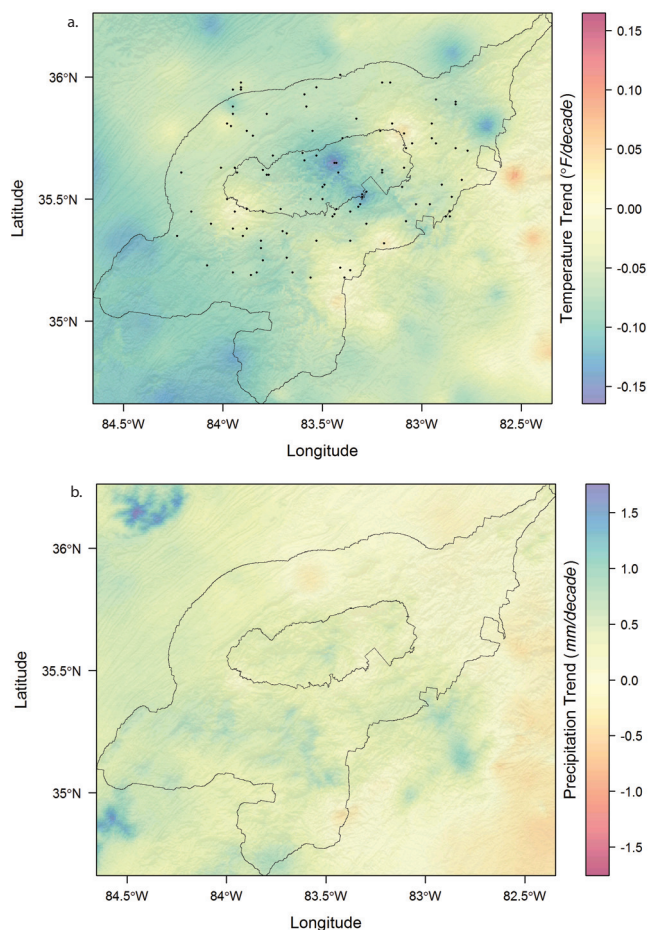
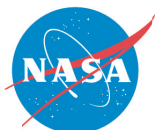


Figure 2. (a) Minimum annual temperature decreased in the park over the last century (1895 – 2006). Locations of select weather stations are indicated by black points. **(b)** Trends in precipitation were slightly positive in GRSM over the last century but were small relative to annual mean precipitation in the Park (calculated by the authors from PRISM data (Daly et al. 1994)).

These low frequency oscillations in sea surface pressure are associated with temperature trends that switch from positive to negative every few decades (Figure 1b).

Precipitation showed no significant linear trend over the last century, although tree ring reconstructions for longer time periods for the southeast indicate that the mid to late 20th century was wetter than



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What We've Observed Cont.

the 18th and 19th centuries (Pederson et al. 2012). Precipitation variability has, however, increased in recent decades, with wet periods becoming wetter and dry periods becoming drier since the late 1970's (Wang et al. 2010). Much of the Park and its ecologically relevant immediate surroundings, hereafter referred to as a protected area centered ecosystem, or PACE, either cooled slightly or experienced no trend in temperature (Figure 2a). Precipitation trends were slightly positive through much of the Park and PACE (Figure 2b). Interpolation artifacts in gridded temperature surfaces can be seen in the “bullseye” patterns associated with weather station locations. NPS weather station comparisons with PRISM data show reasonably good agreement for both temperature and precipitation (Figure 3) although precipitation estimates were considerably more variable.

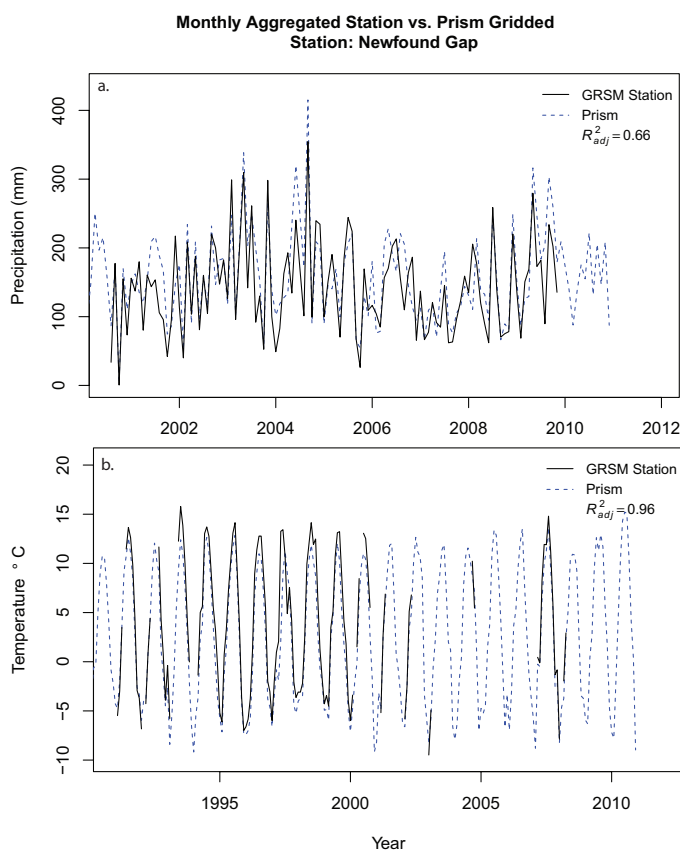


Figure 3. Comparison of 800m PRISM data with Newfound Gap NPS ranger station records (elev. 1646m). (a) Monthly annual precipitation. (b) Monthly minimum temperature.

Projected 21st Century Changes

Recent climate modeling experiments point to the North Atlantic multidecadal oscillation as a potential driver of temperature variability in the southeast (Meehl et al. 2012). Lack of warming in recent decades may also be related to radiative forcing of anthropogenic aerosols (Liebensperger et al. 2012). Higher carbon emissions scenarios using both CMIP3 (Coupled Model Intercomparison Project) (Meehl et al. 2012) and more recent CMIP5 (Kumar et al. 2013) models project warming of several degrees in the southeast, suggesting that the lack of warming observed in the 20th century may not be a persistent feature of the southeast climate system.

Statistically downscaled general circulation models (GCMs) summarized over GRSM project increases on the order of 2°C for both minimum and maximum annual temperatures for a lower emissions scenario (RCP 4.5) while increases approach 6°C under a high emissions scenario (RCP 8.5), which is the trajectory that global emissions are currently tracking (Figure 4). RCPs refer to the amount of radiative forcing, expressed in watts per square meter averaged over the earth's surface (e.g. 4.5 watts/m²), resulting from increased greenhouse gas concentrations in the atmosphere. Differences between RCPs for minimum and maximum temperatures become apparent around 2040 as the trend line for RCP 8.5 steepens, reflecting the greater radiative forcing of higher increased greenhouse gas emissions. Precipitation has historically been more variable in GRSM and this variability is projected to persist, and perhaps increase (Gao et al. 2012, Li et al. 2013). Downscaled GCM projections indicate no trends in precipitation but a wide range of model outcomes between the 25th and 75th ensemble percentiles (Figure 4). Precipitation differences between RCPs are minor.

Dynamically downscaled regional climate models project an increase in heat wave intensity, duration and frequency in the southern Appalachians as well as increases in extreme precipitation events (Gao et al. 2012). Recent analysis of CMIP5 models at their native resolutions also point to a continuation of the 20th century trend of increasing precipitation variability (Li et al. 2013).

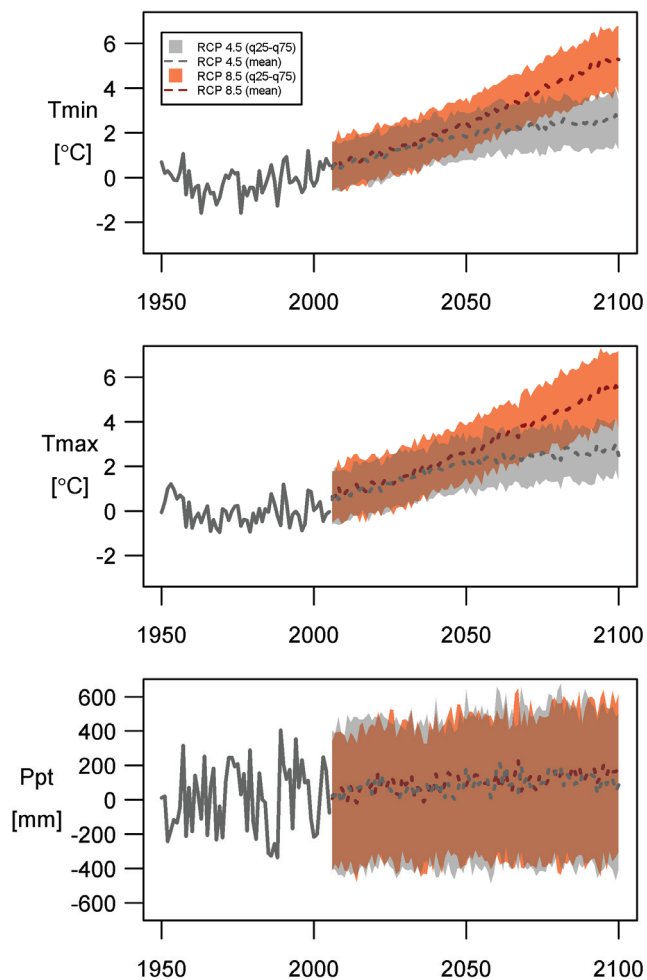


Figure 4. Historical annual minimum temperature, maximum temperature, and precipitation anomalies (solid gray line) and ensemble mean projections (dashed lines) summarized for GRSM. Shaded regions correspond to the area between 25th and 75th ensemble percentiles. Light gray shading corresponds to resource concentration pathway (RCP) 4.5 while orange shading corresponds to RCP 8.5. Historical summaries were obtained from PRISM 800m climate surfaces (Daly et al. 1994) and projections were obtained from NEXDCP-30 downscaled global climate models (Thrasher et al. 2013).

Potential Impacts

Tree Species

Dynamic global vegetation models and correlative models indicate relatively low risk of biome shifts for GRSM (Gonzalez et al. 2010, Hansen et al. 2014). Correlative models of individual species' response to climate change suggest, however, that the relative abundances of particular species and the overall composition of forests may change considerably. For example, climate conditions are forecast to become more suitable for pine species in GRSM and PACE while decreasing in suitability for a variety of deciduous species (Zolkos et al. forthcoming). High elevation species, Fraser fir and red spruce in particular, are expected to experience significant declines

in suitable climate conditions. There has, however, been relatively little evidence, at least in aggregate, that eastern tree species have shifted ranges over the past few decades (Zhu et al. 2012, 2014). Instead, higher temperature tolerances for many eastern tree seedlings relative to adults suggest that demographic turnover may increase before geographic shifts are observed (Zhu et al. 2014).

Aquatic Ecosystems

Changes in the timing and amount of precipitation can have large effects on streamflow and aquatic habitat with concomitant effects on aquatic species (Warren and Bradford 2010). Warming at higher elevations of GRSM is projected to exceed the current thermal limits of a number of salamander species, potentially causing large declines in suitable habitat (Milanovich et al. 2010).

Invasive Insects and Pathogens

USFS National Disease and Insect risk forecasts from 2013 to 2027, <http://foresthealth.fs.usda.gov/nidrm/>, suggest that red oaks and white oaks in GRSM will be heavily affected by oak dieback, with a projected loss of 34% and 28% of basal area, respectively. Oak dieback is a syndrome whereby climatic stressors like drought, flooding, and frost increase oak susceptibility to insects and pathogens. Beech bark disease is expected to take a heavy toll on American Beeches, with a projected 26% basal area loss. Hemlock wooly adelgid and emerald ash borer are forecast to cause losses of 18% and 19% of Hemlock and Ash species basal area, respectively. Dynamic interactions between insects, pathogens, and climate are not included in these models but nonetheless they provide useful first order estimates of the impacts of major disturbance agents in GRSM forests.

Conclusions

Over the next few decades, both minimum and maximum annual temperatures are projected to increase while trends for precipitation are highly uncertain. Climate model experiments suggest an increase in precipitation variability that comes on the heels of an increase in variability over the last century. Drought severity stemming from increased precipitation variability may increase and could be further exacerbated by rising temperatures.

Potential implications of this for GRSM forests include greater risk of mortality from drought stress and greater susceptibility to disturbance agents already present in the Park including Hemlock woolly adelgid and the emerald ash borer. Increased disturbance and higher temperatures may also interact to increase demographic turnover because of differential climatic tolerances of tree seedlings relative to adult trees, leading to potentially rapid changes in forest structure and composition (Klos et al. 2009). Animals, like the Park's outstanding salamanders, will likely be affected by changes in both habitat and in climate suitability. Management and monitoring efforts need to be forward looking with these factors in mind so that potential climate induced impacts can be anticipated and potentially mitigated.

Acknowledgments

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More Information

John Gross, Ecologist, National Park Service, Ft Collins, CO. John_Gross@NPS.gov

Landscape Climate Change Vulnerability Project
<http://www.montana.edu/lccvp/index.html>

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