Climate Change Impacts on Water Availability in Alaska

CHANGES TO HYDROLOGY

Alaska is already showing evidence of climate change. Increases in temperature and changes in precipitation have had profound effects on regional hydrology, including shrinking wetlands, glacier and polar sea ice recession, permafrost melting, and an increase in fire frequency and intensity across the landscape as a result of increased drought and thunderstorms. Continuation of these trends will likely lead to further changes in the hydrologic cycle, with significant implications for the people, places, and wildlife that depend on Alaska's water resources. In an effort to better understand where and when changes in hydrology are likely to occur, we developed a tool for mapping future water availability across the state.

In Alaska's northern climate, most of the precipitation falls during winter months, when it accumulates in the snowpack and contributes to water storage across the landscape. Some of this wintertime storage is lost to cold, dry air through sublimation, but the majority remains until the spring snowmelt converts it to runoff that serves to recharge rivers, lakes, and soils. The greatest losses of water occur during the growing season, when temperatures rise above freezing and evaporation returns water from the landscape back into the atmosphere. Vegetation also depletes water storage as water vapor is lost through transpiration from growing plants.

The term *potential evapotranspiration* (PET) is used to describe the likely amount of water that could be returned to the atmosphere through the combination of evaporation and transpiration. PET is determined by the energy available to evaporate water, measured as temperature, and other environmental conditions including wind, cloudiness, plant growth, and humidity. In Alaska, PET during growing season months typically exceeds incoming precipitation, resulting in an overall water-deficit during this time.

As the climate continues to warm and the growing season gets longer, scientists expect PET and precipitation (P) will both increase. If the increase in water lost from the landscape through PET is not offset by an equivalent increase in incoming P, Alaska may experience more severe water-deficits during the growing season. In order to evaluate potential changes in future water availability over time, we calculated differences between projected monthly estimates of P and PET (P-PET).

ESTIMATING WATER AVAILABILITY

A modified version of the Priestley-Taylor method was used to estimate average monthly PET from climate and landscape data.[1] Climate input variables included mean monthly temperature (°C), maximum monthly temperature (°C), minimum monthly temperature (°C) and cloud cover (%). Landscape classification data was used to calibrate the model to Alaskan ecosystems. These data were combined to produce average daily estimates (mm/d) for each month. Average daily estimates were multiplied by the number of days in each month to determine total monthly PET (mm/mo) before being subtracted from projected monthly P values.

Future estimates of P-PET were derived from averaged monthly data from 5 global circulation models (www.snap.uaf.edu), previously evaluated as best-fit for Alaska.[2] To determine the magnitude of change over time, future projections were compared with a historical baseline, calculated with PRISM (www.prism.oregonstate.edu) temperature and precipitation data and CRU cloud cover data (http://www.ipcc-data.org). Changes in water availability over time reflect differences between projected decadal averages (2040-2049 and 2090-2099) and the 30-yr historical average spanning 1961-1990.

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[1] *Mehta, V.K. Estimating evapotranspiration from weather data. Arghyam/Cornell University, 2006.* www.indiawaterportal.org/data/metdata/ETmanual_onlineversion.doc

[2] *Future estimates are based on the "A1B" emissions scenario from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment, published in 2007. The models used in this analysis included Echam5, Gfdl2.1, Miroc3.2MR, HadCM3, and CGCM3.1.*

PEAK GROWING SEASON WATER AVAILABILITY

Understanding water availability at the peak of the growing season is especially important, as this is when plants require the most water for growth and lakes and rivers experience high rates of evaporation. We have evaluated water availability (P-PET) for all months, but focus on June for characterizing future changes in peak growing season water availability.

For most of Alaska, water lost through PET typically exceeds the rate of incoming precipitation during the peak of the growing season, leading to an overall water deficit during this time (Figure 1a). Our analysis reveals that this water deficit will become even greater in the future due to significant increases in PET without comparable increases in P (Figure 1b and c).

For most of Alaska, this translates to approximately a 10-20% decrease in June water availability in the near future (Figure 1d). Only the colder, high altitude areas of the Alaska Range, Chugach, and Wrangell Mountains are predicted to increase their water storage in June. By the end of the century (Figure 1e), water availability is expected to decrease by more than 30% in Southwestern Alaska, with most of the Arctic and Interior becoming 10 to 30% drier. The most profound changes are likely to occur in areas where sub-freezing temperatures have historically limited PET, but where future warming above freezing will result in greater water losses as PET becomes active.

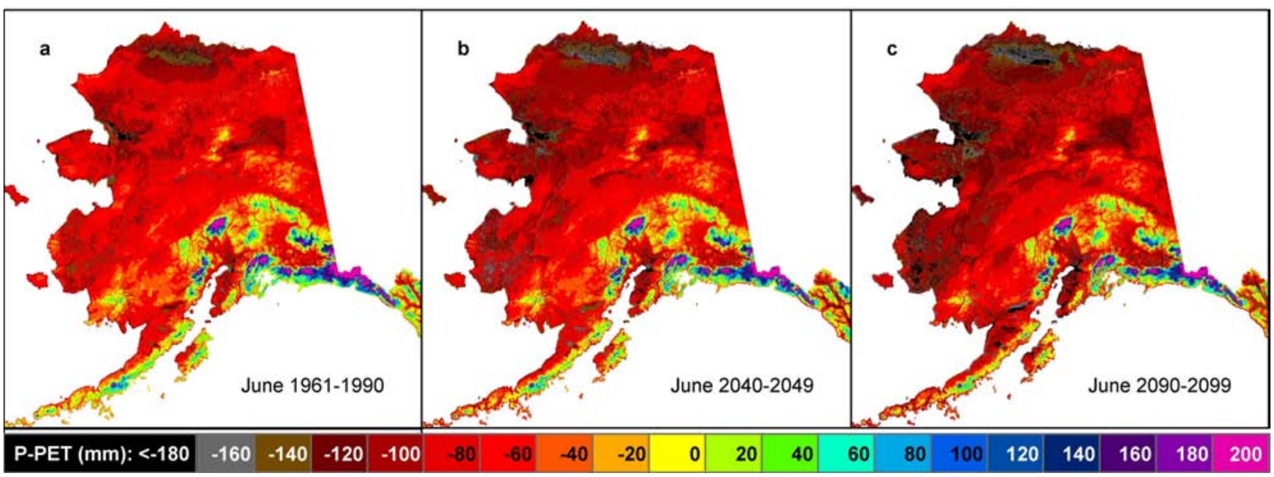
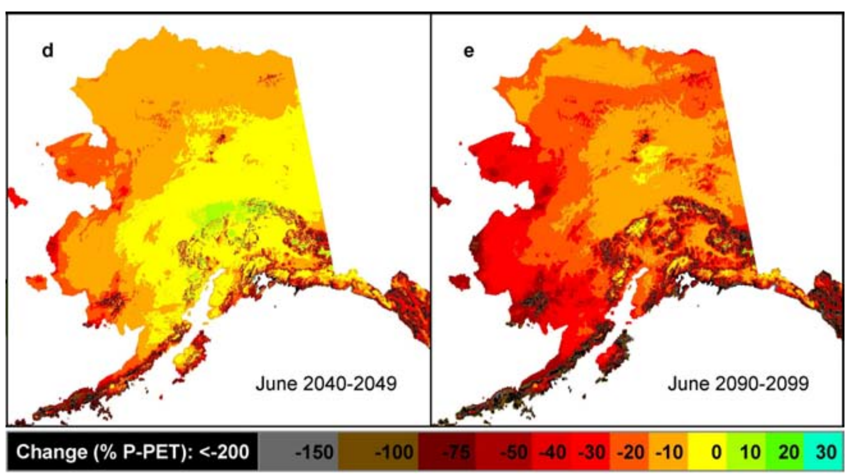


Figure 1. June water availability (P-PET) over the course of the next century (**a**,**b**,**c**).

Percent change in P-PET from historic values (**e**,**f**).



EVAPORATION AND SEASONAL TRANSITIONS

In many areas the growing season will get longer as average spring and fall temperatures rise above freezing. As a result, many areas are projected to undergo a transition from being non-evaporative environments (PET=0; Figure 2a and d) to areas that are experiencing some amount of evaporation (PET>0) in the future. For example, while Southwestern Alaska and the Interior have not historically experienced evapotranspiration during April (Figure 2a), this is predicted to change by 2040-2049 (Figure 2b). By the end of the century most of Alaska south of the Brooks Range is expected to undergo this transition during the spring thaw, with only extremely high altitude areas remaining unaffected (Figure 2c). The Yukon River delta is likely to experience the greatest change.

Similar transitions are expected to occur at the end of the growing season in October (Figure 2d-f), although these increases in PET are not forecasted to be as large as those in April. Southwestern Alaska is likely to experience significant increases in PET by 2040-2049 (Figure 2e). By the end of the century, all but the highest elevations and areas of the Arctic are predicted to experience PET in October (Figure 2f).

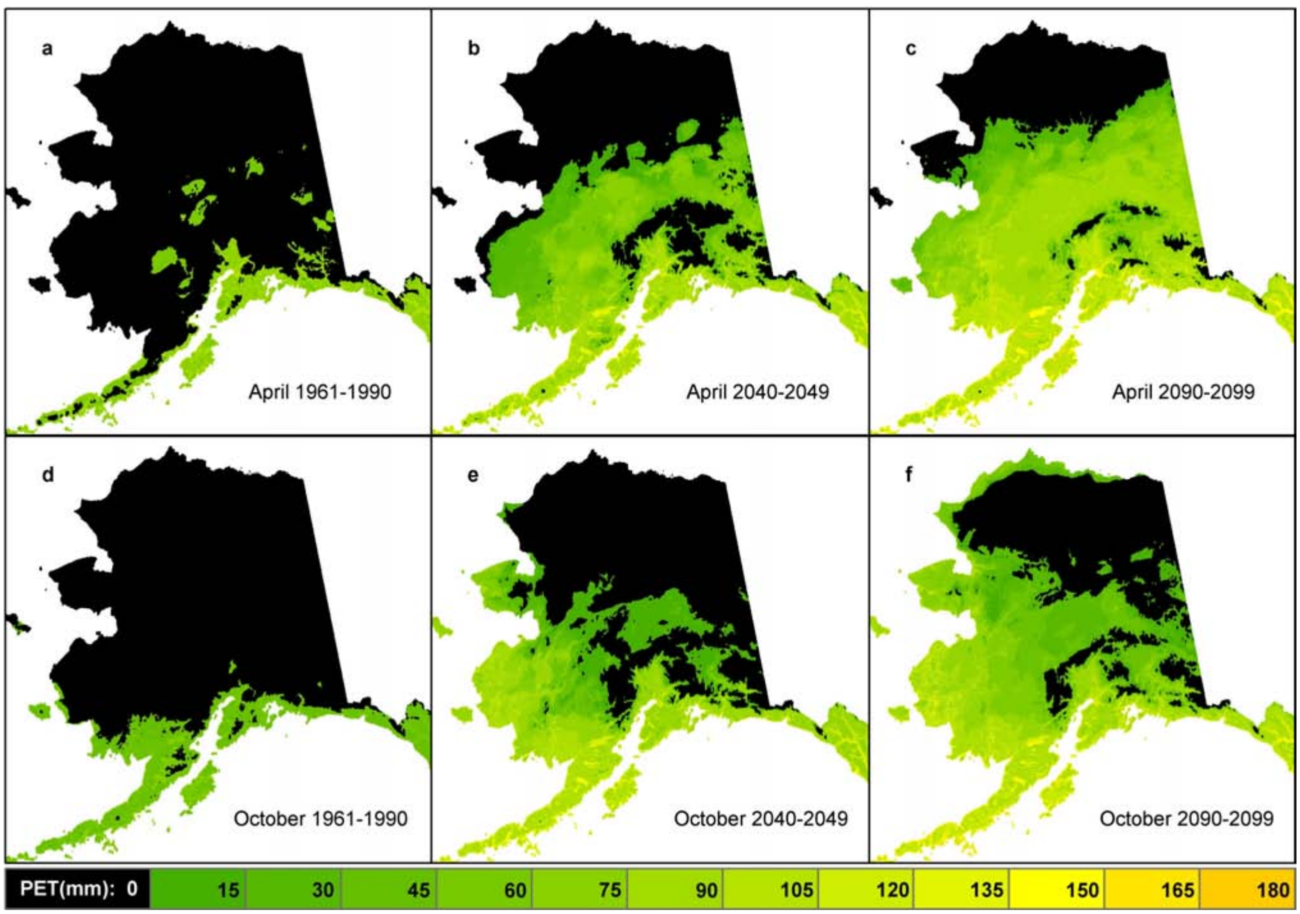


Figure 2. Historical and future estimates of PET during April (**a,b,c**) and October (**d,e,f**). Changes from black (PET=0) to color represent the activation of PET in the future as the growing season becomes longer.

SUMMARY AND RECOMMENDATIONS

The growing season in Alaska is projected to become warmer and drier. With significantly more water leaving the landscape through higher PET than incoming precipitation, June is expected to become 10-30% drier by the end of the century. Such a dramatic decrease in water availability is likely to have profound impacts on the wildlife, vegetation, and human communities that depend on these water resources.

Although much remains uncertain regarding how increased winter water storage may contribute to spring runoff and subsequent growing season water availability, current changes to the hydrologic cycle indicate an alarming trend. Permafrost is melting, glaciers and sea-ice are receding, and wetlands are drying. Thus, the stability of Alaska's freshwater resources is becoming increasingly threatened by climate change and preparing for this future is of escalating importance.

By supplying scientists, land managers, conservationists, and members of the public with a tool for understanding changes in future water availability, we hope to be better prepared to identify species, landscapes or communities that are particularly vulnerable to change. Once connections between the hydrologic characteristics of a region and the natural and cultural resources have been established, stakeholders can focus on developing the most effective measures to facilitate successful adaptation.

It is important to verify the accuracy of predictions about changes in climate and the effects on water availability. By increasing the scope of our current climate and hydrologic monitoring programs, we will be better able to understand the impacts of climate change. The more accurate and complete our observations are, the more successful we will be in updating our predictive analyses and planning for a changing future.


Photo by Brendan O'Brien, 2008

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