Fog has declined in past century along California's redwood coast

February 15 2010

California's coastal fog has decreased significantly over the past 100 years, potentially endangering coast redwood trees dependent on cool, humid summers, according to a new study by University of California, Berkeley, scientists.

It is unclear whether this is part of a natural cycle of the result of human activity, but the change could affect not only the redwoods, but the entire redwood ecosystem, the scientists say.

"Since 1901, the average number of hours of fog along the coast in summer has dropped from 56 percent to 42 percent, which is a loss of about three hours per day," said study leader James A. Johnstone, who recently received his Ph.D. from UC Berkeley's Department of Geography before becoming a postdoctoral scholar in the campus's Department of Environmental Science, Policy and Management (ESPM). "A cool coast and warm interior is one of the defining characteristics of California's coastal climate, but the temperature difference between the coast and interior has declined substantially in the last century, in step with the decline in summer fog."

The loss of fog and increased temperature mean that "coast redwood and other ecosystems along the U.S. West Coast may be increasingly drought-stressed, with a summer climate of reduced fog frequency and greater evaporative demand," said coauthor Todd E. Dawson, UC Berkeley professor of integrative biology and of ESPM. "Fog prevents water loss from redwoods in summer, and is really important for both the tree and the forest. If the fog is gone, we might not have the redwood forests we do now."

The scientists' report will be posted online during the week of Feb. 15 in advance of publication in the journal Proceedings of the National Academy of Sciences.

The surprising result came from analysis of new records recently made available by the National Climate Data Center. The U.S. Surface Airways data come from airports around the country, which have recorded for more than 60 years hourly information such as cloud cover (cloud ceiling height), visibility, wind and temperature.

Johnstone evaluated the data from airports along the northern California coast and found two airports - Arcata and Monterey - that had consistent fog records going back to 1951. With these data, he was able to show that frequent coastal fog is almost always associated with a large temperature difference between the coast and inland areas.

Using a network of 114 temperature stations along the Pacific Coast, Johnstone and Dawson demonstrated that the coast-inland contrast has decreased substantially, not just in Northern California, but along the entire U.S. coastline from Seattle to San Diego. This change is particularly noticeable in the difference between Ukiah, a warm Coast Range site in Northern California, and Berkeley on San Francisco Bay. At the beginning of the 20th century, the daytime temperature difference between the two sites was 17 degrees Fahrenheit; today, it is just 11 degrees Fahrenheit.

The relationship between temperature gradient and fog frequency implies a 33 percent drop in fog along the coast during this time.

Greater fog frequency is connected to cooler than normal ocean waters from Alaska to Mexico and warm water from the central North Pacific to Japan. This temperature flip-flop is a well-known phenomenon called Pacific Decadal Oscillation - an El Niño-like pattern of the north Pacific that affects salmon populations along the US West Coast. The new results show that this pattern may also have substantial effects on the coastal forest landscape.

In addition, the data show that the coast gets foggier when winds blow from the north along the coast, which fits with observations that northerly winds push surface waters offshore and allow the upwelling of deep, cold, nutrient-rich water.

"This is the first data actually illustrating that upwelling along the Pacific coast and fog over the land are linked," Johnstone said.

By pulling in data on temperature variation with elevation, Johnstone and Dawson also related their fog data with a temperature inversion that each summer traps the fog between the coast and the coastal mountains. The inversion is caused by a warm, dry, high-pressure cell that sits over Northern California in late summer, bringing hot temperatures to inland areas, including the Central Valley. If the inversion is strong, its lower boundary at about 1,200 feet keeps a lid on the cool marine layer and prevents fog from penetrating over the Coast Ranges. When it is weak, the ocean air and clouds move upward and inland, resulting in a cooler interior and a warmer, drier coast.

"The data support the idea that Northern California coastal fog has decreased in connection with a decline in the coast-inland temperature gradient and weakening of the summer temperature inversion," Johnstone said.

"As fog decreases, the mature redwoods along the coast are not likely to die outright, but there may be less recruitment of new trees; they will look elsewhere for water, high humidity and cooler temperatures," Dawson said. "What does that mean for the current redwood range and that of the plants and animals with them?"

Eventually, Dawson and Johnstone hope to correlate fog frequency with redwood tree ring data in order to estimate climate trends going back hundreds of years.

"While people have used tree ring data from White Mountain bristlecone pines and stumps in Mono Lake to infer climate change in California, redwoods have always been thought problematic," Dawson said, mainly because it's hard to determine whether the width of a tree ring reflects winter rain, summer fog, temperature, nutrient supply or other factors. "Stable isotope analyses of wood cellulose allows you to pull this data out of the tree ring."

Dawson has established that the isotopes of oxygen in a tree reflect whether the water comes in via the leaves from fog, or via the roots from rainwater. "Redwoods live for more than 2,000 years, so they could be a very important indicator of climate patterns and change along the coast," he said.

The new fog data will allow Dawson and Johnstone to calibrate their tree ring isotope data with actual coastal fog conditions in the past century, and then extrapolate back for 1,000 years or more to estimate climate conditions.

The work was supported by the Save the Redwoods League and the Berkeley Atmospheric Sciences Center.

Provided by University of California - Berkeley