Soil moisture and hot days linked in a global study

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Dry soil in Summer 2011 in Texas. Temperatures increased up to 43°C or 45°C. (Image: Flickr)

(Phys.org) -- For the first time scientists at ETH Zurich have examined globally the connection between soil moisture and extreme heat with measured data. Their study shows that precipitation deficits increase the probability of hot days in many regions of the world. The results will help to better assess heat risks.

In July 2011, a heatwave broke all records in Texas. It did not rain in the region for months. Cornfields and grassland withered, and the soil dried out. For several weeks temperatures were above 38°C, in some places rising even to 43°C or 45°C. The Texan record summer was one example of what climate scientists have also been able to demonstrate in other regions in recent years: if there is a precipitation deficit in the

spring, the probability of heatwaves in the summer increases.

The water content of the soil is not only a decisive factor in ensuring that plants thrive, but it also influences the energy exchange with the atmosphere. If the earth is saturated with water, moisture evaporates from the ground, thus stopping the atmosphere from heating up too quickly. However, once the ground has dried out, solar radiation heats up the air unrestrained.

For the first time, doctoral student Brigitte Müller and Sonia Seneviratne, professor at the Institute for Atmospheric and Climate Science at ETH Zurich, have delivered a global study of the effects of soil moisture with measured data. Their work has just been published in the online version of the professional journal PNAS. On the basis of temperature recordings, the researchers determined the hottest month for all regions of the world and then looked at the precipitation in the previous months based on the standardised precipitation index.

Their statistical calculations show that precipitation deficits and dry soil increase the temperatures in many regions of the world more strongly and quickly. Müller and Seneviratne calculated high correlations for north and south America, southern and eastern Europe, Australia, China and Japan, as well as the southern part of Africa. They also examined extreme events and showed that the mechanism has the most impact at extremely high temperatures.

The occurrence probability of an above-average number of hot days after precipitation deficits is more than 70% in most parts of south America, the Iberian peninsula and eastern Australia, and more than 60% in north America and eastern Europe. After wet conditions in these regions, the probability falls to 30% to 40%.

“We knew that in some regions soil moisture greatly affected the

number of hot days, because we had shown this in other studies; for example, in southern Europe. However, we did not expect this to be the case in so many regions," says Seneviratne. An earlier global study had identified significantly fewer regions. However, this study was based on model simulations and focused only on the months of June to August of one year, and thus overlooked large parts of the southern hemisphere.

Müller, who carried out the analyses as part of her doctoral thesis, stresses that these are probability calculations and not weather forecasts. "However, you can proceed on the assumption that moist conditions reduce the risk of heatwaves," she explains. However, it is not possible to infer subsequent heatwaves from dry conditions with absolute certainty, because both normal and extreme conditions may follow dry conditions. "The summer of 2011 is a good example of this. Although the spring in Switzerland was very dry, there was no strong following summer heat wave," explains Müller. The reason for this was an above-average amount of rain in July, which alleviated the dryness, and a cold front moving in at the beginning of August. A dry spring is indeed a necessary, but not a sufficient condition for the occurrence of heatwaves in the identified regions.

However, the study shows clearly that a lack of soil moisture has a stronger effect for the most extreme hot temperatures. "This finding is decisive, since climate change is causing temperatures to rise further and extremely hot days will become more frequent in the future," explains Seneviratne.

The scientists now want to examine whether existing climate models record the observed effects correctly. These findings would allow more accurate climate projections. Initial results show that the mechanism explains part of the uncertainty of projections of heat extremes in central Europe. They also want to calculate the effects in different regions of the world for different types of vegetation, since soil moisture

evaporates more slowly in forests than in grassland and is also dependent on the soil type. “Our goal is to estimate heat extremes better in the future, to assess the risks and above all to weed out the remaining uncertainties in current climate models,” explains Müller.

More information: Mueller B & Seneviratne S.I. Hot days induced by precipitation deficits at the global scale. *PNAS*. DOI 10.1073/pnas.1204330109

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