Why the Mediterranean is a climate change hotspot

June 17 2020, by David L. Chandler

Global climate models agree that the Mediterranean area will be significantly drier, potentially seeing 40 percent less precipitation during the winter rainy season in the already parched regions of the Middle East and North Africa. Credit: Massachusetts Institute of Technology

Although global climate models vary in many ways, they agree on this:

The Mediterranean region will be significantly drier in coming decades, potentially seeing 40 percent less precipitation during the winter rainy season.

An analysis by researchers at MIT has now found the underlying mechanisms that explain the anomalous effects in this region, especially in the Middle East and in northwest Africa. The analysis could help refine the models and add certainty to their projections, which have significant implications for the management of water resources and agriculture in the region.

The study, published last week in the *Journal of Climate*, was carried out by MIT graduate student Alexandre Tuel and professor of civil and environmental engineering Elfatih Eltahir.

The different global circulation models of the Earth's changing climate agree that temperatures virtually everywhere will increase, and in most places so will rainfall, in part because warmer air can carry more water vapor. However, "There is one major exception, and that is the Mediterranean area," Eltahir says, which shows the greatest decline of projected rainfall of any landmass on Earth.

"With all their differences, the models all seem to agree that this is going to happen," he says, although they differ on the amount of the decline, ranging from 10 percent to 60 percent. But nobody had previously been able to explain why.

Tuel and Eltahir found that this projected drying of the Mediterranean region is a result of the confluence of two different effects of a warming climate: a change in the dynamics of upper atmosphere circulation and a reduction in the temperature difference between land and sea. Neither factor by itself would be sufficient to account for the anomalous reduction in rainfall, but in combination the two phenomena can fully

account for the unique drying trend seen in the models.

The first effect is a large-scale phenomenon, related to powerful high-altitude winds called the midlatitude jet stream, which drive a strong, steady west-to-east weather pattern across Europe, Asia, and North America. Tuel says the models show that "one of the robust things that happens with climate change is that as you increase the global temperature, you're going to increase the strength of these midlatitude jets."

But in the Northern Hemisphere, those winds run into obstacles, with mountain ranges including the Rockies, Alps, and Himalayas, and these collectively impart a kind of wave pattern onto this steady circulation, resulting in alternating zones of higher and lower air pressure. High pressure is associated with clear, dry air, and low pressure with wetter air and storm systems. But as the air gets warmer, this wave pattern gets altered.

"It just happened that the geography of where the Mediterranean is, and where the mountains are, impacts the pattern of air flow high in the atmosphere in a way that creates a high pressure area over the Mediterranean," Tuel explains. That high-pressure area creates a dry zone with little precipitation.

However, that effect alone can't account for the projected Mediterranean drying. That requires the addition of a second mechanism, the reduction of the temperature difference between land and sea. That difference, which helps to drive winds, will also be greatly reduced by climate change, because the land is warming up much faster than the seas.

"What's really different about the Mediterranean compared to other regions is the geography," Tuel says. "Basically, you have a big sea enclosed by continents, which doesn't really occur anywhere else in the

world." While models show the surrounding landmasses warming by 3 to 4 degrees Celsius over the coming century, the sea itself will only warm by about 2 degrees or so. "Basically, the difference between the water and the land becomes a smaller with time," he says.

That, in turn, amplifies the pressure differential, adding to the high-pressure area that drives a clockwise circulation pattern of winds surrounding the Mediterranean basin. And because of the specifics of local topography, projections show the two areas hardest hit by the drying trend will be the northwest Africa, including Morocco, and the eastern Mediterranean region, including Turkey and the Levant.

That trend is not just a projection, but has already become apparent in recent climate trends across the Middle East and western North Africa, the researchers say. "These are areas where we already detect declines in precipitation," Eltahir says. It's possible that these rainfall declines in an already parched region may even have contributed to the political unrest in the region, he says.

"We document from the observed record of precipitation that this eastern part has already experienced a significant decline of precipitation," Eltahir says. The fact that the underlying physical processes are now understood will help to ensure that these projections should be taken seriously by planners in the region, he says. It will provide much greater confidence, he says, by enabling them "to understand the exact mechanisms by which that change is going to happen."

Eltahir has been working with government agencies in Morocco to help them translate this information into concrete planning. "We are trying to take these projections and see what would be the impacts on availability of water," he says. "That potentially will have a lot of impact on how Morocco plans its water resources, and also how they could develop

technologies that could help them alleviate those impacts through better management of water at the field scale, or maybe through precision agriculture using higher technology."

More information: A. Tuel et al, Why Is the Mediterranean a Climate Change Hot Spot?, *Journal of Climate* (2020). DOI: 10.1175/JCLI-D-19-0910.1

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