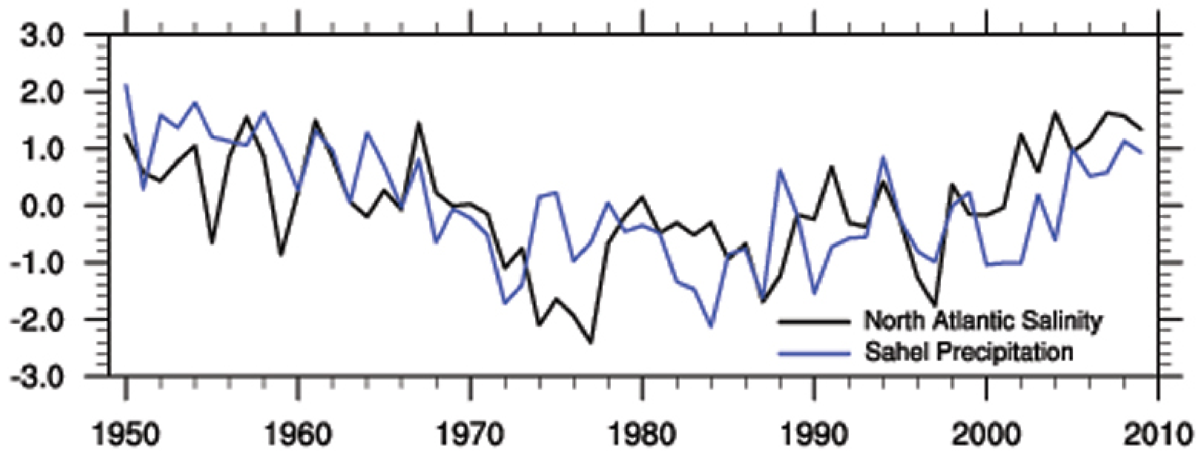
Study offers clues to better rainfall predictions

May 6 2016



Through analysis of sixty years of global salinity and rainfall data, WHOI researchers were able to establish a significant correlation between high springtime salinity levels in the northeastern portion of the subtropical Atlantic and increased monsoon-season rainfall in the African Sahel. Credit: Li, *et al*

The saltiness, or salinity, of seawater depends largely on how much moisture is pulled into the air as evaporative winds sweep over the ocean. But pinpointing where the moisture rains back down is a complicated question scientists have long contended with.

Now, scientists at the Woods Hole Oceanographic Institution (WHOI) have found a potential path to better seasonal rainfall predictions. Their study, which is published in the May 6, 2016 issue of *Science Advances*, shows a clear link between higher sea surface salinity levels in the North Atlantic Ocean and increased rainfall on land in the African Sahel, the area between the Sahara Desert and the savannah across Central Africa.

"We know that higher salinity is a likely signature of increased moisture export from the ocean," said Laifang Li, a postdoctoral scholar in physical oceanography at WHOI and lead author of the study. "So, we were motivated to look at whether salinity, which is typically used to understand ocean dynamics and variations in the water cycle, could be utilized as a predictor of precipitation on land. Our study, for the first time, provides evidence that high springtime salinity levels in the northeastern portion of the subtropical Atlantic correlate significantly with increased monsoon-season rainfall in the African Sahel. This discovery has important predictive value for this region, where even slight variations in rainfall can be a matter of life or death for millions of people."

Salty Signals

The original idea behind the study traces back to 1993 during the Mississippi and Missouri River floods, when Li's advisor, WHOI senior scientist Ray Schmitt, noticed reports of abnormally low salinity in the Gulf of Mexico following the seven-month dousing of the region. "A lot of freshwater had to leave the ocean during that time to supply the extra rainfall on land, so some part of the ocean had to get saltier," said Schmitt.

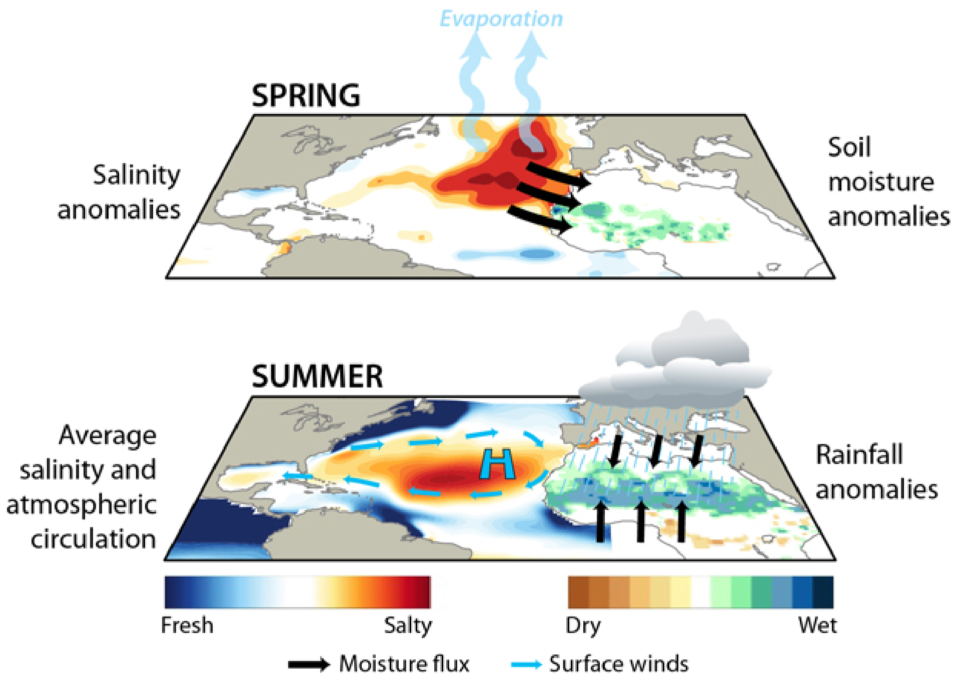
Each year, an estimated 100,000 cubic miles of water evaporates from ocean surface waters - enough to flood our entire lower 48 states to a depth of 60 yards. About 90 percent of this moisture falls right back into the ocean as precipitation - a vast recycling of moisture that represents the bulk of the global water cycle. But about 10 percent of the evaporated water gets carried over land where it falls out as rain.

"This basic idea had me looking at the high-salinity areas of the ocean to see if the surface salinity variations could be used for rainfall predictions," said Schmitt.

Region of Interest

In an attempt to use ocean salinity as a natural rain gauge, Li and WHOI co-authors Schmitt, Caroline Ummenhofer and Kris Karnauskas (now at the University of Colorado) poured through sixty years of global salinity and rainfall data, including detailed salinity maps generated by NASA's salinity-sensing satellite, Aquarius. During a multi-year NASA mission that began in 2012 known as the Salinity Processes in the Upper Ocean Regional Study (SPURS), Aquarius helped identify a patch of the North Atlantic with the highest salt concentration anywhere in the open ocean. Schmitt and other colleagues then deployed moorings and autonomous ocean robots there to collect additional data on salinity levels. Later on, Li and Schmitt drew a box around the area and began looking at the historical salinity and rainfall data in hopes of answering the central question: where did all the fresh water go?

"We wanted to know what this region of maximum salinity was telling us about rainfall in other places," said Li. "Through analysis of water transport dynamics in the atmosphere, we were able to see that excessive moisture exported from the North Atlantic went straight to the African Sahel."



Top: Winds evaporate water from the subtropical North Atlantic ocean, leaving behind high levels of salinity during the spring. The exported moisture makes its way to the African Sahel, where it soaks the arid land and gradually builds up soil moisture over the course of three months.Bottom: The soil moisture couples with convection in the atmosphere to create a feedback loop that draws in additional moisture from the North Atlantic and Mediterranean. This increases precipitation during the summer African monsoon season. Credit: Jack Cook, Woods Hole Oceanographic Institution

But the cause-and-effect takes some time to develop—several months, in fact. It turns out that while the subtropical North Atlantic had the saltiest anomalies in the spring, the Sahel was the wettest during summer monsoons. The three-month delay surprised the scientists."Our first thought was that the water would get transported from ocean to land rather quickly - within a matter of weeks - since the winds can be pretty quick," said Schmitt. "So seeing the increase in precipitation months later was a mystery."

Upon closer analysis, they discovered that as moisture entered the Sahel, it turned to rainfall and gradually soaked the region's bone-dry landscape throughout the spring. As moisture accumulated in the soil, the soil began pulling more energy from the sun and driving convection in the atmosphere, ultimately creating a feedback loop that drew in more moisture from the North Atlantic and Mediterranean. This resulted in increased rainfall when the summer monsoons hit.

Brighter Outlook for Rainfall Predictions

According to Li, ocean salinity not only helps pinpoint rainfall, but it can outperform rainfall forecasts based on sea surface temperature, which has been the standard for many decades.

"As part of our study, we used machine-learning algorithms which were able to compare the importance of different variables used in rainfall prediction models for the Sahel region," said Li. "The algorithm ranked salinity as the most important one."

Co-author Caroline Ummenhofer commented: "What is impressive about these salinity signals is how strong and clear they are, and how much lead time they give for rainfall predictions. The sea surface temperature patterns we investigated here give mainly a simultaneous correlation with rainfall on land and are therefore not all that useful as a predictor. For certain land areas, salinity stands out as a true predictor quite independent of the ocean temperature patterns."

According to Schmitt, the promise of more reliable seasonal rainfall forecasts could have a significant socioeconomic impact on the Sahel, where periodic droughts and resulting famines put millions of people at risk of food insecurity and malnutrition.

"If farmers know it's going to be a relatively dry year, they may decide to not plant certain crops, plant water stress-resistant crops, or start planting earlier in the year," said Schmitt. "Water managers would know whether to release more or less water from reservoirs and when to impose water restrictions. And relief agencies could move supplies around based on the amount and timing of rainfall expected during the monsoon season. It could help save millions of lives."

Tony Lee, a scientist and salinity expert with NASA's Jet Propulsion Laboratory, agrees. He says that accurate prediction of seasonal rainfall is key to agricultural planning and the livelihoods of people in the Sahel region.

"This study demonstrated that ocean salinity can be used to improve the skill of Sahel rainfall prediction, and underlined the values of the integrated observing system approach to address actionable Earth System Science questions that have important societal implications," said Lee.

Having successfully linked North Atlantic salinity with rainfall in the Sahel, the WHOI team has begun applying their techniques to other regions. They recently correlated high springtime salinity in the northwestern portion of the North Atlantic with summer rainfall in the U.S. Midwest, and have a "whole list of other places" they want to investigate.

"We see a great deal of potential for improved forecasts in China, India, and other regions that rely heavily on monsoon rains to keep the crops going," said Schmitt. "But making this all work in other areas will require that the existing climate monitoring network is maintained and expanded. The more data we have, the easier it will be to improve seasonal climate forecasts and anticipate extreme droughts and floods."

More information: "North Atlantic salinity as a predictor of Sahel rainfall" *Science Advances*,

advances.sciencemag.org/content/2/5/e1501588

Provided by Woods Hole Oceanographic Institution