As drought dried up rivers and reservoirs across Europe this year, grim warnings from the past surfaced from the depths. *Wenn du mich siehst, dann weine*, read the inscription on a "Hunger Stone" exposed on a bank of the River Elbe in the Czech Republic: "If you see me, then weep."

Still, as bad as the drought appeared on the surface, a new satellite analysis estimating freshwater availability in Europe shows that "what's even worse is the groundwater story that people cannot see," says the hydrologist Jay Famiglietti, director of the Global Institute for Water Security at Canada's University of Saskatchewan.

Famiglietti and collaborators analyzed two decades of data from the U.S./German satellite missions known as GRACE to find the rate of change in freshwater stored on the European continent. GRACE's twin satellites track changes in gravity to measure large stores of water such as those held underground in aquifers; flowing in lakes and rivers; and frozen in ice sheets and glaciers. The larger the water mass, the stronger the gravitational pull.

The results suggest a steady depletion of water in aquifers—the porous rock and soil layers underfoot that store most of the world's non-frozen freshwater—between 2002 and 2022. With some exceptions including Scandinavia, most of the continent is losing far more groundwater each year than is being replaced by rainfall and other recharge, Famiglietti says.

The researchers estimate average overall water loss in Europe at about 84 gigatons a year since the turn of the 21st century. It's an alarming rate, Famiglietti says, roughly equal to all the water in Lake Ontario, or five times the average annual flow of the Colorado River through the Grand Canyon. The scale—a gigaton represents a billion tons of water—is almost impossible to wrap your mind around. But that's the scale at which climate change is happening.

The underlying cause is clear, he says. Too little in some places and too much in others, "water is the messenger delivering the bad news of climate change" to people around the world. But excessive groundwater extraction plays a significant role in the losses.

Climate change and aquifer over-pumping are tied together in a tough knot. As severe droughts become more frequent, agricultural, industrial, and urban users pump more water from greater depths to compensate for lack of rain and record heat. Aquifers can't recover as they could when the rains returned after historic droughts like those marked on the Hunger Stones of the former Bohemia.

GRACE and other models are part of the growing and urgent case for better understanding and management of aquifers, says the Paris-based hydrogeologist Alice Aureli, chief of groundwater sustainability and water cooperation at UNESCO. This year's drought was the worst in 500 years, according to European Commission scientists. The specter of scarcity has “made even the water-abundant countries afraid,” Aureli says. “Unfortunately, people take action only when they are afraid.”

The GRACE missions

The Gravity Recovery and Climate Experiment, a mission of NASA and the German Aerospace Centre, first sent its pair of satellites into orbit in 2002. The two work like a balance scale, tracking change over time by measuring water’s gravitational pull. The amount of water on Earth remains constant, and the freshwater we need for life is only a sliver of the total. But climate change and other human alterations—from draining wetlands to damming rivers or pumping aquifers—can move that freshwater in significant and dangerous ways, drying a lake or unleashing a flood.

The original GRACE mission, which ended in 2017, “showed us critical things like our global map of groundwater depletion—and that the human fingerprint on the freshwater landscape is the dominant actor,” Famiglietti says. It also showed that the world’s mid-latitudes, including the U.S. Southwest and much of Europe, are drying as predicted by the Intergovernmental Panel on Climate Change (IPCC). But the drying is not in some distant future; it’s happening now—faster than IPCC projections.

In 2018, the U.S. and Germany launched GRACE Follow-On, nicknamed GRACE-FO, a carbon copy of the original mission. GRACE-FO has revealed how little progress has been made in protecting the world’s freshwater, Famiglietti says. “We are simply continuing down the same downward path and in some places, worse,” including in Europe.

The new GRACE data “ground-truths” what other computer models reveal about aquifer depletion, says Marc Bierkens, a professor of hydrology at Utrecht University in the Netherlands. He and other modelers have long sounded the alarm about the acceleration of groundwater losses as pumping for irrigation, industry, and public supply outpaces the rate of natural recharge.

Working with researchers from the International Groundwater Resources Assessment Center and Deltares, Bierkens’ team has also shown how aquifer depletion contributes to global sea-level rise. Most of the groundwater pumped up from wells does not return to its aquifer but eventually evaporates and becomes rain. That rain falls either directly into the ocean—or onto land that then drains to streams and rivers and ultimately to seas. Bierkens estimates groundwater’s contribution to sea level rise at 10 to 15 percent, “large enough to be taken into account when understanding where current sea level rise is coming from.”

While GRACE and other satellite models are good at “picking up big patterns,” Bierkens says, the continental scale is also their disadvantage. Communities and nations can’t manage groundwater sustainably without a clearer picture of its natural and human vagaries: How water recharges, moves through and leaves local aquifers. What specific crops, industries, and urban demands are tapping the water below. Soil types and depths. Vegetation and trees. The hardscapes keeping water from making its way back underground.

Bierkens is leading an effort to build thousands of such variables into a grid-based groundwater model that covers Earth’s land area in more than a hundred million square-kilometer cells, each a window to the aquifers below. Layered with weather, land-use and other datasets, the model can help clarify the extent to which water losses are being driven by pumping versus climate change and other variables, as well as the solutions possible—the projected effects, say, of restored wetlands, reduced pumping, or recharge projects.

Out of sight, out of mind

Whether from space or a square-kilometer grid, helping people see the fate of groundwater is fundamental to saving it, says UNESCO’s Aureli. Unlike in rivers, where what happens upstream becomes obvious to those living downstream, groundwater’s flow can be disturbed and changed in subtle and surprising ways. There is also a protective sense, “that this is my water, no one can see what I have, so why should I tell them?” Aureli says. “This can be my reserve.”

That mystery and invisibility put the world’s most important source of available freshwater out of sight and out of mind for too long, Aureli says. But this year’s drought emergency revealed the urgency to better safeguard water in the face of scarcity that can desiccate grain harvests in Italy, shutter nuclear reactors in France, and close off major shipping arteries in Germany.

Member governments of the UN convene regularly around major crises such as climate change, most recently at COP27 in Egypt, and biodiversity losses, the focus of COP15 this month in Montreal. But UN member states have not been able to agree to come together to negotiate on water in nearly half a century. Aureli attended the Mar Del Plata UN Conference on Water in 1977 as an 18-year-old college student tagging along with her father, who was also a hydrogeologist. Hardly anyone was talking about groundwater back then, she says.

The story will be different in spring 2023 when the UN convenes its second major intergovernmental water conference, in New York City. As a lead-up to that meeting, a special groundwater summit this Wednesday and Thursday at UNESCO headquarters in Paris focuses in part on how nations can better share aquifers that span political boundaries. Familglietti will present some of his team’s new satellite findings—being prepared for publication this spring by colleague Hrishikesh Chandanpurkar and others—and make a case for water’s importance in COP and other climate negotiations. Unlike the days when groundwater was shrouded in mystery, “now we have facts in hand,” Aureli says.

Wealthy nations also have solutions at hand, says the Danish hydrogeologist Karen Villholth, director of South Africa-based Water Cycle Innovation. Those include ecological restoration, aquifer recharge, and managing demand. Denmark, for example, has cut per-capita water use in half, from nearly 200 liters a day in the 1980s to closer to 100 liters today, she says. Increasing the cost of water, and a focus on reuse and other efficiency measures, have helped make the difference.

Groundwater could also be a “game-changer” for climate justice, Villholth says, given that it’s over tapped in high-income countries and under-developed in low-income ones. As wealthy nations overcome water waste, they can support low-income nations in developing aquifers for basic water supply and small-scale businesses. “Why are most poor countries, like in Africa, not getting support to develop their groundwater resources,” she asks, “when they have not induced a hotter and more hostile climate?”

Still, much like climate denial, the myth of freshwater abundance remains entrenched despite mounting evidence otherwise. No recent European water strife reveals it better than Tesla’s first manufacturing plant on the continent. Southeast of Berlin, Gigafactory Berlin-Brandenburg is ramping up in an area beset by declining groundwater levels. When a reporter last fall questioned CEO Elon Musk about local concerns that the plant will usurp water from the community and ecosystems, he laughed aloud and called her “completely wrong.”

“It’s like water everywhere here,” Musk said. “Does this seem like a desert to you? It’s ridiculous. It rains a lot.”

Planned expansion of the plant has been delayed amid the severity of this year’s drought, National Geographic writes.