THE GOOD NEWS, if you ask Richard Seager, an oceanographer at the Lamont-Doherty Earth Observatory in Palisades, New York, is that the Northern Hemisphere Hadley cell is not expanding as fast as some recent analyses have warned. Those projections, he says, depend upon comprehensive satellite data, which have been available only since the late 1970s, a brief slice of time. He thinks the observed Hadley cell expansion is better attributed to a naturally occurring decadal shift in Pacific Ocean currents.

The bad news, however, is that, because of Hadley cell expansion and other factors, the Southwest is moving — and to some extent has already moved — into a new set of climate conditions “unlike any climate state we have seen in the instrumental record.” Seager thinks that the droughts of the past, like the Dust Bowl drought of the 1930s and the 2000–2004 drought that killed millions of pinons and ponderosas in New Mexico and Arizona, will be the norm of the future. He is saying, in effect, that what we think of as drought today will cease to be drought in the light of some not-too-
Drought is relative — and exceptional. One does not say that the Saharais experiencing drought. The Sahara is dry by nature, not by exception. According to Seager, the future Southwest will be much drier than the conditions its present inhabitants consider “normal”; it will likely be as dry as its driest recent decades, and people will have to recalibrate their expectationsto a new idea of what “normal” stands for. Moreover, he says that the droughtsof the future will be superimposed on that dryness and that they will be unlike anything people in the region have known since late medieval times.

Seager holds an endowed position at Lamont-Doherty, a research arm of Columbia University. He’s a Brit who came to the United States for education and stayed. I visited him at his Morningside Heights apartment on a day when the lab was closed and his son Angus was home from school, contending with homework at the dining table. The humid smell of laundry was in the air. We had plenty of time to talk, but not an unlimited amount — an important football game (real football, played with the feet) would be televised from England that afternoon. Seager lives close to Columbia, only a block from the diner made famous by the sitcom “Seinfeld.” He takes an amused pride in this link to American pop culture, marveling at the tourists posing for snapshots and the occasional
celebrity guiding a tour. Seager is abit of a cultural sponge. As we talked, he alluded frequently to the intricacies of Colorado River politics and to Dust Bowl histories and books on western water. Except for his accent, he could have been a good-old-boy insider. Seager calls himself an oceanographer and meteorologist, avoiding the term climatologist, which suggests, to him, a duffer “with a cloth cap and a rain gauge in his garden.” He came to the study of the Southwest “by pure chance, which is the way science goes, you know?” He and his team had been looking at Asian monsoon variability in the nineteenth century, going back to 1856, the year the British and American navies began recording air and sea surface temperatures and winds from all their ships. Other navies and merchant marines eventually followed suit, making it possible to compile a nearly global century-and-a-half record of oceanic weather. Seager and his team drew upon that data to model relationships between sea surface temperature and changes in atmospheric circulation. In 2004, Siegfried Schubert, a scientist at the nearby NASA Goddard Institute for Space Studies, a leading center for climate science, wrote a paper that linked the Dust Bowl drought to small temperature changes in surface waters of the tropical Pacific. Seager had access to an advance copy. “When Schubert published that paper, and actually before it came out,” says Seager, “I just looked in the model that day and said, well, does our model produce a Dust Bowl drought? And sure enough, it produced a Dust Bowl drought.” Further
investigation showed it “made a nice big drought in the Southwest in the 1950s,” which Schubert’s simulation had missed, and it also showed the Southwest turning dry in 1998, the approximate onset of the drought that produced widespread tree die-offs in 2002–2003. Things were getting interesting. Seager checked the model against a new drought atlas that Lamont-Doherty’s tree-ring researchers had just produced and found that they jibed: the model tracked the wet and dry periods recorded in the tree rings for the mid- to late nineteenth century with high fidelity. “So we just sort of dropped stuff, whatever we had been doing, and misused government funds to fund this research instead of what the government had actually given us funds to do.” His program managers didn’t complain, because they understood the importance and opportunities of the new work. “So we pushed it forward.” The forwardness was in two dimensions: forward in terms of refining an understanding of historical drought records and forward also in time, projecting climate for the Southwest into the twenty-first century.

The Intergovernmental Panel on Climate Change (IPCC), which the United Nations established in 1988, had also done this. Modelers contributing to the IPCC’s “Fourth Assessment Report,” which appeared in 2007, concluded that the North American Southwest would grow appreciably drier in the twenty-first century, but their predictions focused far in the future, past 2080. They also concerned themselves solely with precipitation, not the finer-grained interaction of precipitation
less evaporation, which better describes the moisture available to nourish soil and discharge into streams and rivers. "So there’s a bit more to the story than the precipitation" — and Seager and his team set out to tell it. Their simulations showed that the Southwest would not have to wait until 2080, or even 2050, to experience drier times; greater aridity was already on its doorstep — hence the considered use of the word imminent in the title of their paper, "Imminent transition to a more arid climate in southwestern North America," which appeared in the journal Science in 2007, attracting considerable attention. Their research also told them that the increase in aridity would not result from the same forces that triggered the droughts of the past. Those droughts, possibly including the extended droughts of medieval times, appear to have occurred when the currents of the tropical Pacific, for whatever reasons, carried relatively cool surface waters far to the east, toward the Americas. This pattern, commonly called La Niña, seems to give a northward push to the winter storm track that brings moisture to western North America. The opposite pattern, El Niño, pulls the storm track southward, bringing winter rain to U.S. deserts and snow to the southern Rockies. (Mexico is not so lucky; it depends principally on summer monsoons.) Together El Niño, named for the Christmastime arrival of warm waters off the coast of Peru, and La Niña, its contrary sister, are known as the El Niño Southern Oscillation (ENSO). The mnemonic for this relationship, from a southwestern point of view, is sexist: the
boy child brings welcome winter precipitation, filling the reservoirs crucial to both cities and agriculture, but the girl brings drought. Or so it has been in the past. The model simulations analyzed by Seager and his team showed the Southwest to be drying out “for a different reason, and that different reason is just a simple consequence of warming up.” Seager explains that when Earth’s surface and its atmosphere warm up, two things happen. One is the intensification of the hydrologic cycle: warmer air holds more water vapor; more vapor converges in wet regions, and it rains more there. “The pattern of water vapor transport intensifies. That makes dry regions drier and wet regions wetter. So that’s part of why the Southwest dries, because it’s already in one of these places where important parts of the atmosphere circulation take moisture away.” The other reason Seager cites is the expansion of the subtropical subsidence zone, where the dry, downwelling air of the Hadley cell returns to the surface of the land. “And that’s not the same as what causes the natural droughts,” he concludes. “The cycle of natural dry periods and wet periods will continue, but they continue around a mean that gets drier. So the depths — the dry parts of the naturally occurring droughts — will be drier than we’re used to, and the wet parts won’t be as wet as we’re used to, because they’re both happening around a mean state that gets drier and drier.” That new “mean state” is what he calls the new climatology of the Southwest, something similar to the Dust Bowl or the 1950s — a far cry from the anomalously wet
period that ran from the late ’70s into the ’90s, which forms many people’s notion of what is “normal” for the region. Not everyone agrees with Seager’s message, and certainly not with the blunt, alarming language in which he delivers it. There are always cries for more data and improved models, for further analysis at a finer spatial scale, and for the consideration of other possible explanations. There are also critics who say that even if he is right, he should be more careful: predictions as strident as his risk undermining the public’s faith in the scientific community. What if the Southwest enjoys a string of generously wet years? Every system exhibits variation, and all long droughts include wet episodes. What if the new climatology arrives late, or not at all? Perhaps then the urgency he has tried to engender will turn to cynicism, commitment turn to inaction, and the public’s grudging acceptance of the reality of climate change degrade into disbelief. Perhaps, in the end, his startling warning might have an effect opposite to the one he intended. Seager shrugs: “It’s because of things like that that the Bureau of Reclamation and their like can sort of throw their hands in the air and say, ‘Well, what do we do with these climate model projections? They don’t have information at the spatial scale we need to predict what the Colorado River is going to do.’ And they’re right, strictly speaking — that’s correct, but that’s not a good excuse for not doing anything, because the chances are, once you get a model with all the right spatial scales to have all the topography, it’s probably not going to change the
sign of the result.” The sign, plus or minus, would still be a minus in terms of water availability — things will be getting drier. “So if you just do nothing and wait for that, you’re just wasting time. . . . It could be ten, fifteen years before you get the models at the resolution you need, by which time you’re probably deep into this drying trend.”

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LEOPOLD’S PREDICTION WAS correct, except for the prophecy of a tourist road. The integrity of the Gavilan did not last long after his 1936 visit. He came back for a second hunt at the close of 1937, bringing his brother Carland eldest son Starker, and this experience was as enchanting as the first. He also urged in various quarters that the area be preserved as “an internationalexperiment station” to serve “as a norm for sick land on both sides of the border.”

29 But nothing came of his proposal. Game began to decline in the mountains in subsequent years, and the outfitting business in Colonia Pacheco was all but dead by 1941. 30 Shortly after Leopold’s death in 1948, his son Starker returned to the Rio Gavilan hoping to initiate some of the ecological studies his father had dreamed of, but the paradise he remembered from a decade earlier was gone. Logging roads threaded through the headwaters and livestock had followed. Many stretches of the formerly moss-hung river had become a scour of cobbles. The downward ecological spiral of the Rio Gavilan continues to the present. 31 In the all-too-familiar cycle that Leopold in his early days documented throughout Arizona and New Mexico, logging and overgrazing bared the land to the violence of
storms. Deprived of its defense of grass, litter, and living roots, the soils of the slopes yielded to the force of downpours, and floods tore every soft thing from the rivers and creeks, leaving rocky gutters in their place. The damage was a kind of sin against the land, which Leopold captured in one of his best metaphors: “Somehow the watercourse is to dry country what the face is to human beauty. Mutilate it and the whole is gone.”

Many are the accounts of southwestern watersheds that unraveled. In one of his essays on Mexico, Leopold cites Will Barnes’s telling of the destruction of valley lands along the San Simon River in Arizona. In “Pioneers and Gullies” (1924), Leopold himself describes the loss of 90 percent of the cultivated land along the Blue River in Arizona’s White Mountains. Elmer Otis Wooton, in a seminal 1908 monograph, The Range Problem in New Mexico, recounts how deepening arroyos cut the life out of the Mangas Valley in the Burro Mountains. These and other reports point unmistakably to human agency as a trigger for widespread erosion, if not through logging and grazing then as a result of roads, trails, and other disturbances that guttered runoff and initiated the formation of arroyos. Just before his first trip to the Gavilan, Leopold drafted an extensive discussion on this topic, which he titled “The Erosion Cycle in the Southwest.” Dutifully, he sent the essay out for review, including a copy to the eminent Harvard geologist Kirk Bryan, a native of New Mexico who had closely studied arroyos in Chaco Canyon and other southwestern locations. Bryan and many of his colleagues...
maintained that climate, not human activity, governed arroyo formation and that, independent of human influence, the Southwest had repeatedly undergone alternating periods of degradation — arroyo cutting and stream entrenchment — on the one hand, and aggradation — the building up of alluvial lands — on the other. Bryan’s critique evidently prevented Leopold from settling his mind on the subject of arroyo formation, and “The Erosion Cycle in the Southwest” was never published. But he did not let the matter rest. He urged his son Luna to go to Harvard to study with Bryan and get to the bottom of the issue. 33 Not many families pass intellectual conundrums from one generation to the next, but the Leopold family was in a class by itself. All five of Leopold’s children became accomplished naturalists, and three, Starker, Luna, and Estella, achieved election to the National Academy of Sciences. 34 Luna’s dissertation, “The Erosion Problem of Southwestern United States,” was not completed until after his father’s death, but the conclusion he reached neatly bridged the points of view of his father and his mentor. Near the end of his own life, he restated it in a book, A View of the River, that sums up his life’s work as a hydrologist: “The deep gullies cut by erosion in pre-Columbian time took less than 200 years to evacuate a large part of the early Holocene fill. In the period 1880–1920, overgrazing and climate change repeated the events of A.D. 1200–1400 in a period of less than 50 years.” 35 Luna Leopold had concluded that climate and geology control cycles of large-scale erosion, but also that
human activity, like an enzyme in a biological reaction, accelerated the process markedly. The relative weights accorded to climatic and human causes of arroyo formation are important. If climate is the sole cause, then clear-cutting a watershed or grazing it to the point that it can’t hide a golf ball might alter its biota and ruin its productivity, but the gullies that subsequently take form would have formed anyway. Such a view is nonsense, as both Leopolds well knew, and the Rio Gavilan was their proof. The watershed of the Gavilan did not unravel during the arroyo-cutting heyday of 1880–1920. It came apart later, after its timber was cut, its grass removed, and its slopes braided with roads and trails that concentrated the energy of storm runoff on newly exposed targets. The most reasonable conclusion, in fact, might be stated less conservatively than the restrained scientist Luna Leopold was willing to do: namely, that the way people treat the land influences arroyo-cutting considerably, and that the influence is especially great when climatic factors favor downcutting and degradation. Two key factors are important to understand: effective aridity and storm energy. In the period 1880–1920, when most of the valley arroyos in the western states were cut, total precipitation did not differ markedly from other periods of similar length, but more precipitation appears to have come from heavy storms, and less as light rain. A light rain — what some Pueblos call a female rain — falls slowly and gently. It soaked the ground, and a large proportion of its water becomes available to plants. Under a regime of abundant light rain,
which would normally mean many mild storms, the vegetative cover of the land tends to increase. By contrast, heavy rains — male rains — quickly saturate the topmost layer of the soil. During the downpours, the water falls so fast that it soon exceeds the absorptive capacity of the soil, and most of it runs off, sometimes in violent flash floods. Only a small portion remains behind to nurture plant growth. As a result, a period with many violent thunderstorms and few light rains is effectively more arid than a period in which light rains produce the same total amount of moisture. As aridity increases, the protective clothing of the land — in the form of vegetation, leaf litter, and other organic matter — decreases, making the soil more vulnerable to the increased energy of those big, wild, violent male rains. If all this sounds familiar, it should. The prospect of bigger, more violent storms coupled with increased effective aridity is part of the bundle of effects predicted for the Southwest as a result of climate change. In the early 1990s, Luna Leopold put the matter bluntly: “The climatic changes of the past suggest that if the trend toward a warmer and more arid climate actually continues in the coming decades, the erosion of alluvial valleys seen in the thirteenth century, and again in the nineteenth, will be repeated in many of the semiarid areas of the planet where the rainfall is primarily of the thunderstorm type.”

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