Ethnoclimatology in the Andes: A cross-disciplinary study uncovers a scientific basis for the scheme Andean potato farmers traditionally use to predict the coming rains
Author(s): Benjamin S. Orlove, John C. H. Chiang and Mark A. Cane
Source: *American Scientist*, Vol. 90, No. 5 (SEPTEMBER-OCTOBER 2002), pp. 428-435
Published by: Sigma Xi, The Scientific Research Society
Stable URL: http://www.jstor.org/stable/27857722

Ethnoclimatology in the Andes

A cross-disciplinary study uncovers a scientific basis for the scheme Andean potato farmers traditionally use to predict the coming rains

Benjamin S. Orlove, John C. H. Chiang and Mark A. Cane

Across the Andes in Peru and Bolivia, farmers gather in small groups in the middle of the night in late June. They climb high ridges and often ascend to the peaks of mountains. Coming right after the winter solstice, these nights are the longest of the year and among the coldest as well. Hundreds of such groups of villagers assemble on these nights in a large area that extends from Huancayo, located some 12 degrees south of the equator, to Potosí, which lies at 19 degrees south. The farmers huddle together in eager expectancy. They are waiting for the moment when they can see the Pleiades, a star cluster in the constellation Taurus.

Benjamin S. Orlove received his Ph.D. in anthropology from the University of California, Berkeley in 1975. He is a professor in the Department of Environmental Science and Policy at the University of California, Davis and is an adjunct research scientist with Columbia University's International Research Institute for Climate Prediction. Over the past dozen years or so, Orlove has concentrated his studies on the indigenous people of the Andes. He recently published a book, Lines in the Water *(University of California Press), about the people and cultural practices found around Lake Titicaca. John C. H. Chiang received a Ph.D. from Columbia in 2001 for studies of climate dynamics. A faculty member in the Department of Geography at U.C. Berkeley, he is currently a fellow at the Joint Institute for the Study of the Atmosphere and Ocean, part of the University of Washington, Seattle. Mark A. Cane obtained his doctorate in meteorology from the Massachusetts Institute of Technology in 1975. He is the G. Unger Vetlesen Professor of Earth and Climate Sciences in the Department of Earth and Environmental Sciences and the Department of Applied Physics and Applied Mathematics at Columbia, where he holds a joint appointment at the International Research Institute for Climate Prediction. Address for Orlove: Department of Environmental Science and Policy, University of California, Davis, CA 95616. Internet: bsorlove@ucdavis.edu*

At this time of year, the Pleiades become visible low in the northeast sky only as dawn nears. The farmers believe that they can use the particular appearance of the Pleiades to forecast the timing and quantity of precipitation that will fall in the rainy season, months later. Although this odd form of astrology might seem just a quaint superstition (like the Groundhog's Day ritual familiar to Americans), our research has, in fact, uncovered its scientific basis.

Our project began after two of us (Orlove and Cane) independently heard of these forecasts. Orlove first came across them in 1973, while conducting field research in the southern Peruvian Andes for his doctoral dissertation in anthropology. Curious to witness the yearly event, he arranged to join a group of indigenous farmers who gathered atop the nearest large mountain to await the appearance of the Pleiades above the horizon. He wrote an article about this practice, which is part of the festival of San Juan, celebrated each June 24th. But he focused on the social mechanisms that led people to form the groups and didn't consider the accuracy of the forecasts themselves. And once that article was finished, he dropped the topic. His notes from that first field work remained buried in a drawer.

Cane learned about this Andean ritual much later, while on vacation in Peru in 1994. On a hike with his wife—less than 150 kilometers from Orlove's field site—he struck up a conversation with the local guide about weather and climate. The guide mentioned the forecasts to him. They tickled his curiosity. It seemed to him, a specialist in climatology, that there might be some scientific basis to them. He took detailed notes, including the name of the Pleiades in Quechua, the indigenous language. After his return home, he raised the subject from time to time with people who he thought would be interested. One day in 1996, a graduate student in anthropology whom Cane knew suggested that he might discuss the matter with Ben Orlove—a not-so-common name that Cane recognized immediately. As it happens, the two had grown up six blocks from each other in Brooklyn and attended the same schools. Although they had been in regular touch as children and as teenagers, they had not seen each other in a quarter-century.

An exchange of email messages ensued, and as they began to discuss the stories they had heard in South America, they found that they shared a common set of reactions. On the one hand, it seemed completely extraordinary. How could the appearance of stars possibly be connected to rainfall? And how, indeed, could people even remember the appearance of stars from one year to the next? Their belief, and the agricultural practices connected to it, seemed as implausible as foretelling the outcome of a battle by examining the intestines of a sacrificed bull. On the other hand, it wasn't impossible. There are many areas in which indigenous knowledge of this sort has shown its worth. Aspirin and quinine, for example, were once no more than folk remedies. Agronomists often turn to peasant farmers for their knowledge of local crop varieties. And in many parts of the world, architects are adopting the traditional building styles of desert peoples in recognition that these designs represent energy-efficient solutions for arid climates. If some cases of traditional knowledge have a sound footing in medicine, agriculture and ar-

Figure 1. Growing potatoes in the high Andes of Peru and Bolivia is arduous, given the rugged conditions and the limited resources of most local residents. Perhaps that difficulty helped inspire indigenous farmers to work out their system of forecasting the rains using simple astronomical observations. The authors show that the method practiced in this part of the Andes is remarkably reliable and has a sound scientific basis. (Photograph courtesy of Bruce Winterhalder, University of California, Davis.)

chitecture, there might be such instances in atmospheric science as well.

These discussions soon led to the idea of writing a paper. Cane proposed that one of his students (Chiang) join the effort. The son of a Taiwanese diplomat, Chiang grew up in South Africa and was interested in development issues in Third World countries. His dissertation was on mechanisms of climate variability in the tropics, and he was intrigued with the prospect of applying his training to a societal problem.

Our combined knowledge and expertise were thus well suited to the investigation at hand. Furthermore, in the course of his anthropological field work, Orlove had lived in rural areas of the Andean highlands for more than three years and was familiar with the rhythms of potato agriculture in that region. The villagers there must live within the tight constraints imposed by the elevation and climate and by the basic requirements of the crop. There is a distinct growing season during rainy months of the year, usually from October through March. These are also the warmest months and have the longest days, so they are best for crops. However, potatoes have stringent requirements. If soil moisture remains too low after the tubers are planted, they will not produce strong shoots. If the ground freezes, the plants will be damaged. The farmers, well aware of the need for proper soil moisture and air temperature, aim to plant their potatoes right at the start of the rainy

Figure 2. Twelve villages *(red circles)* located in the Andes of Peru and Bolivia were the focus of the authors' study.

season, so that they will be assured of an adequately long period with appropriate conditions.

Climate and agronomy are not the only concerns that focus the farmers' attention on the planting dates of potatoes; the spatial and temporal organization of their agriculture also has this effect. They work any particular field only for a year or two and then leave it uncultivated for several years, so that the fertility of the soil can recover. This fallow period also reduces the impact of nematodes, which often attack the potatoes. These pests decline during fallow years, whereas continuous cultivation increases their populations and threatens the health of the crop.

Coordinated Efforts

In hundreds of villages in the Peruvian and Bolivian highlands, households synchronize the cycle of planting and fallowing. Why? Because villagers graze their flocks on the grasses and low plants that grow in fields during fallow years, it is a great convenience for them if the cultivated fields lie near one another, at some distance from the pastures to which they bring their sheep, cattle and llamas. This coordination reaches impressive levels and often involves thousands of individual plots covering, in total, many square kilometers. Because the villagers drive the herds from the fields before they are first cultivated after being left fallow, it is imperative for them to reach agreement on the date of planting.

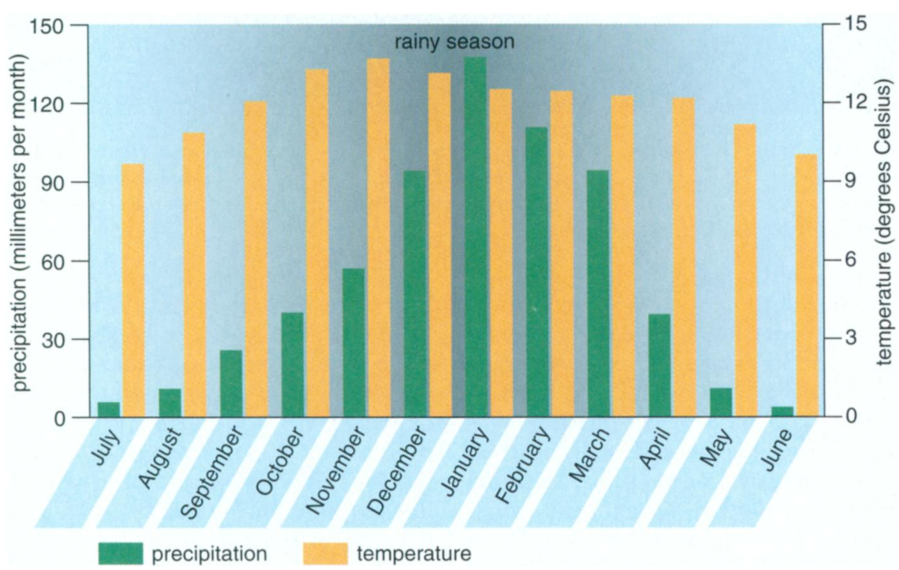

Figure 3. Yearly weather cycle for the region under study is reflected in the monthly mean temperature and precipitation for four sites from which the authors were able to obtain reliable records. The rainy season *(dark background)* extends, roughly, from October through March.

It was clear to us, then, that Andean farmers have a powerful motive to learn the nature of the coming rainy season. Accurate forecasts would reduce their risk of crop loss and would assist them in their complex task of coordinating the planting. And we had a strong hunch that their scheme could be connected with a well-known phenomenon of tropical climate: El Niño. The unusual warming of the sea surface in the eastern equatorial Pacific that heralds an El Niño is known to change weather and climate patterns all over the globe. Because this 800-pound gorilla of natural climate variability lives next door, it seemed entirely plausible to us that it might affect the Andean highlands by influencing the precipitation during the wet months (October through March) and by doing something—we were not sure what—to alter the apparent brightness of the Pleiades in June, well before the rainy season begins.

How could we unravel this mystery? Clearly, our first task was to assemble a fuller account of what goes on there. So we combed through major and minor academic journals, old collections of folklore, compendia on indigenous technology and unpublished doctoral dissertations. From these sources we established a list of 12 villages, distributed throughout a single contiguous region of the Andes, where farmers view the heavens in June to predict rainfall months later.

Their beliefs, we discovered, are quite similar from place to place. The villagers all concur that the Pleiades are the stars to be observed. Some state simply that they look to see whether the cluster is bright or dim. Others mention that they also consider whether the Pleiades are visible before June 24th or whether they appear only on that festival date or even after. In some places, villagers report that they evaluate the size of the cluster.

Interestingly, these observations are all closely connected to the relative clarity of the atmosphere. For example, the "size" of the Pleiades varies with atmospheric transparency because when the dim stars become visible, the number of Pleiades members increases from 6 to 11 or so, and the apparent diameter of the cluster grows by 25 percent. In two villages farmers mentioned that certain stars appear to

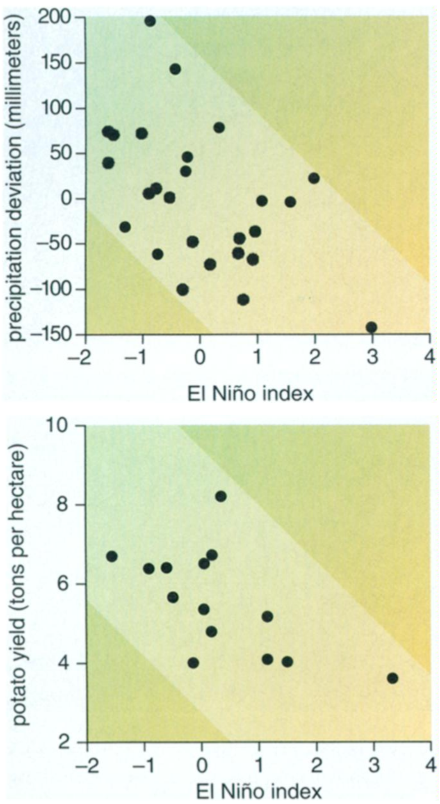

Figure 4. Summer rainfall in the study area, expressed here as a deviation from the mean value, varies inversely with the intensity of El Niño conditions, which are tracked using an index of severity *(top)*. As a consequence, potato yield in this region varies inversely with the intensity of El Niño *(bottom)*.

"split" when viewing conditions are best. We take this to mean that they are able to see additional, dimmer stars close to other, brighter ones. Only one of the observed attributes puzzled us: Villagers state that the brightest star in the cluster can shift its position relative to the others. Although one star in the cluster is significantly brighter than the others, we never did decide just how it could seem to be located in different places. Perhaps it appears to shift its relative position on the clearest nights when the dim stars come into view.

In studying the details of the practice, we were struck by the fact that the villagers place enough credence in such stargazing to act on it. In years when the Pleiades are bright, large, numerous or otherwise favorable, they plant potatoes at the usual time. However, when the Pleiades are dim, small, scanty or otherwise unfavorable, they anticipate that the rains will arrive late and be sparse, so they postpone planting by several weeks. This use of the forecast to alter planting dates was evident for 10 of the 12 villages. The reports we had for the other two villages did not provide enough information on activities there after June to determine whether or not the local farmers altered their planting schedule.

Accuracy Counts

The key question, of course, was whether this traditional method does the farmers any good. To answer it, we needed first to document fluctuations in precipitation and potato yield. After that, we had to explore a range of natural, El Niño-linked causes that could influence naked-eye observations of the sky.

The first task required our finding atmospheric data sets to complement the anthropological information that we had already assembled. Chiang examined Andean meteorological data drawn from a global collection of the National Oceanic and Atmospheric Administration. Such data sets (especially those from developing countries) are often too short for examining year-to-year variations, may contain significant gaps and are generally unreliable. Nevertheless, he was able to extract four stations representative of the region where the forecasts are made—Ayacucho, Cusco and Juliaca in Peru, and La Paz in Bolivia—each with relatively complete records from July 1962 to June 1988. These weather observations demonstrate what we had surmised. There is indeed a strong linkage between El Niño and precipitation: Rainfall is decidedly lower during El Niño years. This relation is particularly evident for the three months of highest precipitation, December, January and February. It is interesting to note that October rainfall is also diminished by El Niño, suggesting that the rainy season starts later in these years.

It was somewhat more difficult to obtain information on potato yields, because the great majority of the farmers, who live scattered in remote villages, do not report their harvests to any organization. However, the International Potato Center near Lima, one of the major international agricultural research centers, had collected data for the total weight of potatoes harvested and for the total area planted in several provinces in the Puno department in Peru—fortunately for us, right in the middle of the region of interest. These statistics show a strong connection between climate variability and potato yields, which are significantly lower in El Niño years. Because potatoes are sensitive to drought, it makes sense that they feel the effects of the lowered precipitation El Niño brings. The higher-than-normal temperatures during an El Niño may also stress the crop.

Having linked both precipitation and potato yields to El Niño, we turned to the next task: looking for some atmospheric factor that would connect this

Figure 5. Simulated view of the Pleiades as they might appear during a normal year, when high cirrus clouds do little to obscure the night sky, shows 11 stars visible *(top)*. Looking at the cluster during an El Niño year, when high cirrus clouds are more abundant, would reveal fewer stars *(bottom)*. Conditions between these extremes would, in turn, allow an intermediate number of stars to be seen *(middle)*.

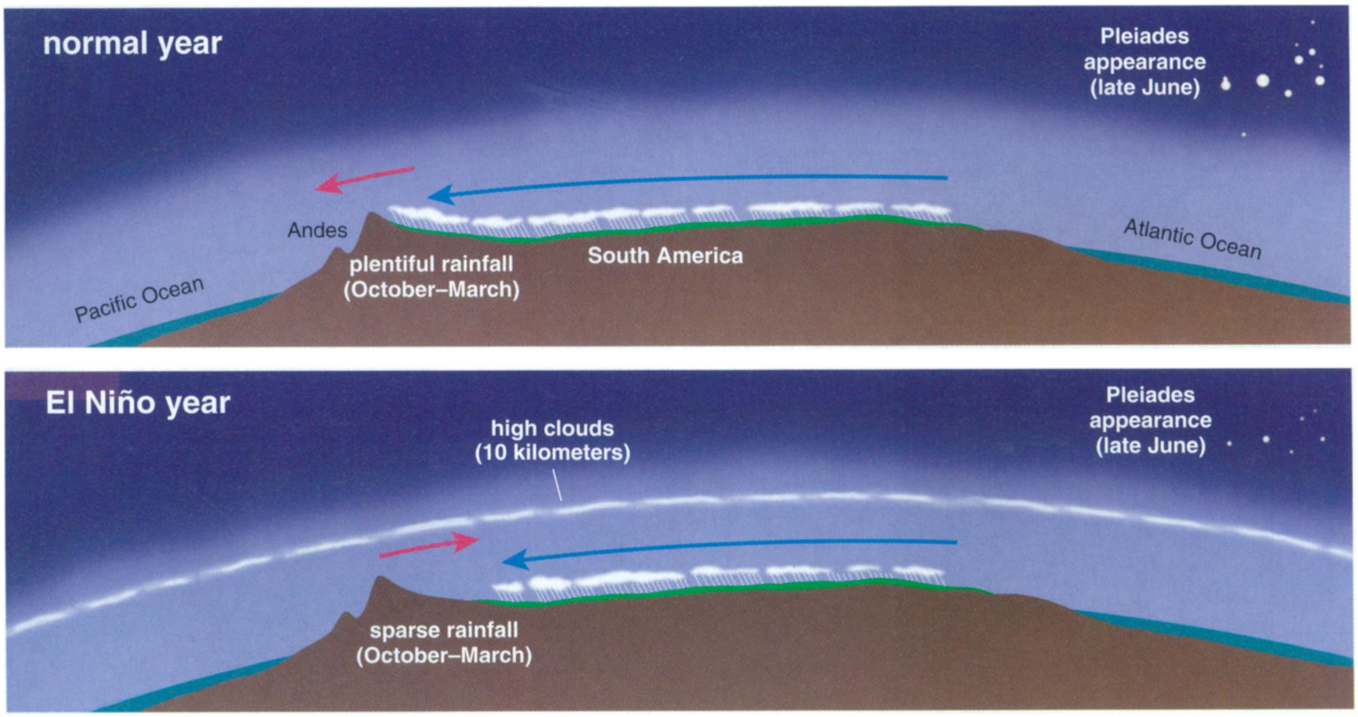

Figure 6. Although the high-level summer winds passing over the Andes are variable, in a normal year *(top panel)* this flow is, on average, from east to west *(red arrow)*. These winds thus help to bring some of the moist air moving west from the northern Amazon basin and then south along the flanks of the mountain chain *(blue arrow)* up into the Andes proper. El Niño causes the high-level summer winds to blow, on average, from west to east, which inhibits the import of this humid air and creates a markedly drier season for the farmers of the region *(bottom panel)*. They are, however, able to forecast the amount of rain to expect during the summer using the midwinter appearance of the Pleiades as a guide: Because El Niño also creates an obscuring layer of thin, high cloud over much of the tropics, the Pleiades appear dimmer when dry conditions are in store.

climatological phenomenon with the apparent brightness of the Pleiades. Colleagues in the field of observational astronomy directed us to a set of well-established equations that describe the effect of various atmospheric variables on the apparent brightness of stars. Because the Pleiades are close to the horizon when the traditional observations are made, the villagers view these stars through a much greater amount of air than they would if the cluster were closer to the zenith. Thus the influence of atmospheric clarity is comparatively large.

We considered a variety of hypotheses. First we looked into the possibility that the air above the Andes contains more dust in El Niño years. Joe M. Prospero and coworkers at the University of Miami had previously shown that trade winds carry large quantities of Saharan dust across the tropical North Atlantic to the Americas each year (see "The Global Transport of Dust," May–June), and there was some suggestion that El Niño modulates this transport. With the help of Reha Cakmur at the Goddard Institute for Space Sciences, we examined satellite observations, but the result was disappointing: There was little evidence for significant dustiness over the Andes. Furthermore, because of its weight, dust in the atmosphere tends to concentrate low down—typically the first few kilometers above sea level—so Saharan dust isn't likely to affect the Andean highlands.

At the suggestion of Gene Rasmussen, a meteorologist at the University of Maryland, we decided to focus on another possible culprit: high cloud. This might seem an unlikely candidate. After all, most clouds are so thick that they block starlight entirely. And the shallow viewing angle that the Andean forecasters have for the Pleiades means that the starlight has to go through a lot of atmosphere. However, the tropical clouds at elevations above 10 kilometers are not typical clouds—rather, they are what meteorologists call high cirrus. Although these wispy clouds scatter light to some extent, they are so thin that they cannot be discerned with the naked eye. Their *optical thickness* (equivalent, in rough terms, to the fraction of light attenuated as it passes through the cloud) is about 3 percent or less. Hence, they are often termed "subvisual."

This hypothesis appeared to work. High-cloud amounts, as compiled by the International Satellite Cloud Climatology Project (ISCCP), showed an increase during El Niño years in the area to the northeast of the Andean highlands (the direction one looks to view the Pleiades) during late June.

The evidence from ISCCP was suggestive but not definitive, because the high-cloud category in that data set includes not just thin cirrus but other types too. Fortunately for us, we could draw on measurements from a spaceborne sensor that is particularly sensitive to clouds above 10 kilometers: The Stratospheric Aerosol and Gas Experiment II (SAGE II), an instrument carried on the Earth Radiation Budget Satellite, gauges optical thickness by measuring the intensity of sunlight after it enters the Earth's atmosphere at a grazing angle and escapes to space again. Unlike the imaging used for the ISCCP, which looks straight down at the atmosphere, the SAGE II method can detect extremely thin clouds.

A previous analysis of this SAGE II data, published by Geoffrey S. Kent of the Science and Technology Corporation in Washington, D.C., and his coworkers, suggested that subvisual cirrus vary strongly with El Niño. Using their results and taking into account the viewing angle of the Andean forecasters, we estimated that the resultant dimming of the Pleiades for an El Niño year compared with a normal year is between 0.1 and 1 astronomical magnitude—that is, the relative brightness of the cluster changes by a factor between 1.1 and 2.5. Thus these high clouds can diminish the brightness of the Pleiades considerably but even at their thickest do not make the star cluster disappear.

It was indeed fortunate that both the ISCCP and SAGE II data sets were available, because either on its own would not have been enough to make a strong case: The ISCCP data set had sufficient spatial and temporal resolution to link high clouds with El Niño; however, it was only barely sensitive enough to detect thin cirrus. In contrast, the SAGE II data had the required sensitivity to thin cirrus but lacked spatial resolution and did not cover a sufficiently long period. Taken together, however, they point to high, thin clouds as the link between the farmers' observations and El Niño.

Still, we explored other possible atmospheric influences on the apparent brightness of the Pleiades. In particular, we drew on the experience of amateur astronomers to come up with other plausible mechanisms. One such possibility is a change in the water vapor content of the atmosphere. Another is atmospheric turbulence, which is known to make stars appear fuzzy. It turns out that both these parameters increase during an El Niño, tending to make the Pleiades dimmer. Moreover, higher levels of water vapor and greater turbulence are generally associated with cloud formation. Nonetheless, the direct effect of these variables on Pleiades brightness is small compared with cloudiness.

There is another reason to think that high, subvisual clouds are indeed governing these forecasts. Such clouds are long lasting: Their numbers do not vary nearly as dramatically as clouds lower down in the atmosphere, which change daily with the weather. Thus farmers who view the Pleiades on a single night are likely to obtain an accurate estimate of the typical amount of high cloud—a convenient proxy for climate conditions over the eastern Pacific, which control whether it will be a normal or an El Niño year.

It is still not understood how subvisual clouds form or why their coverage over the tropics increases during El Niño years. One possibility is that plumes of convection in the atmosphere lift moisture to the upper troposphere, where this water vapor condenses into ice crystals, creating high cirrus clouds. Such convective activity is known to increase over the tropical Pacific during El Niño. So more subvisual clouds may form there and then, carried by strong upper-level winds, spread over the rest of the tropics, including the Andean highlands.

A few reports bearing on this phenomenon and its relation to Andean rainfall have emerged since we mounted our scholarly investigation of this topic three years ago. In particular, a detailed empirical study by Mathias Vuille of the University of Massachusetts, Amherst, and coworkers using more complete station data and sophisticated analysis has put the link between El Niño and Andean rainfall on a sounder statistical footing. Another study, by Rene Garreaud and Patricio Aceituno (both at the University of Chile) proposed a very interesting mechanism that might well explain how the various El Niño signals in the Andean highlands are all connected. They note that during El Niño, the flow of wind over the Andes tends to be more often from west to east than the other way around. This prevents, in good measure, humid air over the slopes and lowlands east of the mountains from traveling up into the highlands. Because this is the primary conduit for bringing moisture to this region, rainfall diminishes.

In sum, this research shows that the apparent brightness of the Pleiades in late June indeed correlates with rainfall during the growing season for potatoes in the following October through March. To our knowledge, this is the first time a scientific explanation has been offered for the workings of a folk meteorological practice. This case is particularly striking, because most farmers in more developed countries do not use seasonal climate forecasts. In the United States, for example, fewer than 10 percent of all farmers draw on seasonal forecasts to modify their operations.

The Scorecard

As is so often the case, to answer one riddle is to pose others. This research has touched off four questions in particular. The first is the accuracy of the forecasts. Our assessments here are incomplete. The correlation coefficient between high cirrus clouds in the predawn hours in late June (the ones responsible for dimming the Pleiades) and the precipitation in the following rainy season (as determined from satellite observations) is about −0.3, which corresponds to a forecast accuracy of around 65 percent. This exceeds the accuracy of modern scientific forecasts with similar lead times for precipitation over the Andean highlands, which ranges from 55 to 60 percent.

Figure 7. In summer, humid air from the Amazon basin travels up into the high Andes, carrying moisture to this rugged region. That process is evidenced by the clouds seen in this view of a mountain pass on the eastern escarpment, which also features a church situated some 4,500 meters above sea level. (Photograph courtesy of Bruce Winterhalder, University of California, Davis.)

village	year	June indicator	June forecast	outcome in following year
Sicuani	1973	dim stars	poor harvest	poor harvest
Cuyo-cuyo	1986	dim stars	poor harvest	poor harvest
Cuyo-cuyo	1987	bright stars	good harvest	good harvest
Chayantaka	1991	late appearance	poor harvest	poor harvest
Chayantaka	1992	large, bright stars	good harvest	good harvest

Figure 8. Five predictions based on sightings of the Pleiades have been documented. Remarkably, all five proved reliable.

Of course, naked-eye observations of the Pleiades provide an incomplete measure of high clouds. So one naturally wonders whether the forecasts made by Andean villagers are very valuable. We have found only five cases in which investigators recorded the June predictions and then remained in the field, or returned to the study site, to see whether the predictions were borne out. Remarkably, in all five cases, the forecasts were correct. Because there are only two categories—good years and bad years, which are roughly equal in number—this situation is similar to announcing that one can predict how a tossed coin will land and being correct five out of five times. If the proportion of good and bad years is equal, this level of accuracy would come about by chance only about 3 percent of the time.

Recent findings of a group of investigators from the University of Missouri also support the validity of the Andean farmers' method. These investigators studied indigenous peoples around Lake Titicaca, in the same region as our study. The villagers in this area observe the Pleiades, but also consider a number of other factors, such as the flowering of plants and the behavior of birds, in making their predictions about the coming rainy season. In this area, villagers accurately forecasted the drought in 1989–90 and the normal rains of 1990–91 and 1997–98, the three rainy seasons that the group studied most closely. A sample of only five—or eight, if the Titicaca cases are included—is insufficient to provide a firm figure for the accuracy of the forecasts. But our contacts in Lima report that the Peruvian Ministry of Agriculture is undertaking a project to study the local forecasts and their accuracy, and so a better evaluation may be possible in a few years.

This project, and others like it, could do far more than simply compare these two systems, modern and traditional; it could explore their complementarities as well. Atmospheric scientists may benefit from having their attention directed to the phenomena that indigenous people observe, in this case the thin high cloud in a specific region, much as indigenous farmers could consider attributes of the atmosphere other than the ones that they already note. Each group could gain insight from the other—much as modern physicians sometimes take advantage of traditional medicines, and traditional healers visit pharmacies.

A second question is the origin of these practices. Their wide distribution suggests that they have had a long history, as does the fact that they are deeply embedded in other indigenous beliefs in the Andes. The villagers find it quite reasonable that the Pleiades would be large in years when the rains and the harvests are abundant. Their convictions are based on the assumption of consistency and correspondence of many features in the natural world and on the notion that years are coherent temporal units. The Pleiades are among the first signs that they can observe in the new year, which in their

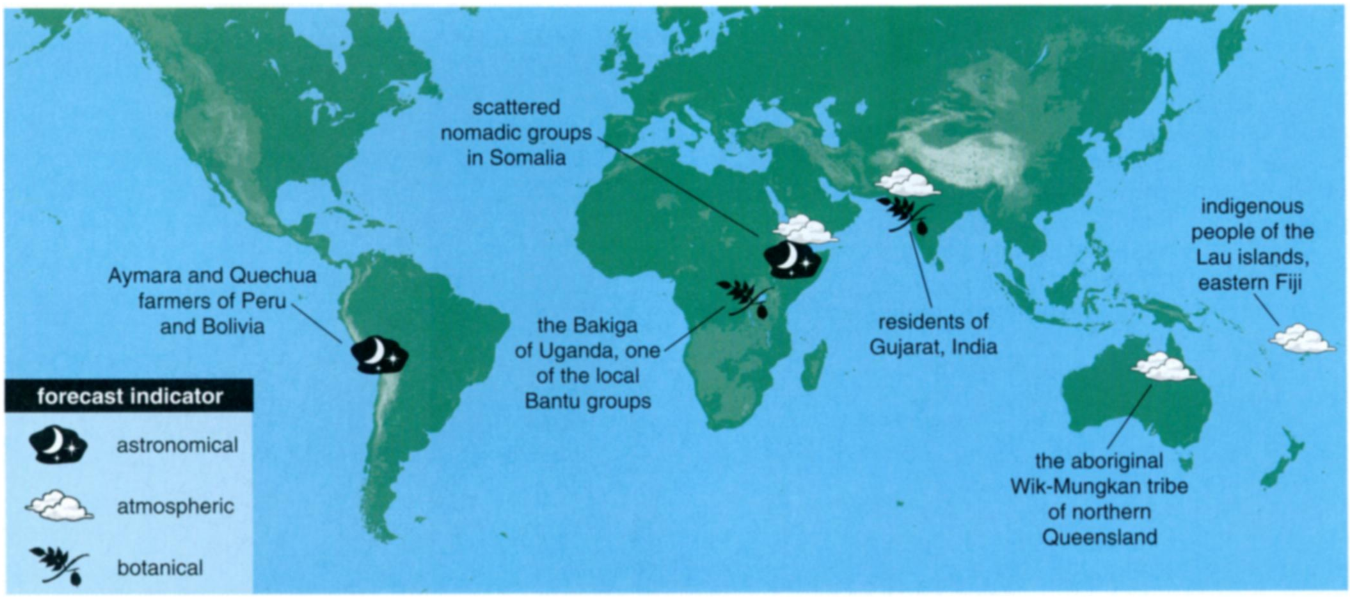

Figure 9. Local and indigenous groups in several parts of the world attempt to forecast climate conditions using simple observations of their environment. Those instances depicted here have recently come to the attention of the authors, who are assembling information about such practices worldwide. Curiously, such predictive schemes appear to be most common in tropical latitudes. Where other examples exist and how much such folk wisdom can be counted on remain open questions. In any event, these forecasts demonstrate which aspects of the climate their practitioners hope to discern and when reliable predictions would be of value to them.

systems of reckoning starts around the winter solstice.

Our earliest firm date for this form of forecasting is the late 16th century. One source written just around 1600, from the northwest end of the area that contains the 12 villages, includes the following item in its list of stars: "Next are the ones we call the Pleiades; if they come out at their biggest people say, 'This year we'll have plenty.' But if they come out at their smallest people say, 'We're in for a very hard time.'"

The year 1600 is fairly close to 1532, when the Spaniards began the conquest of the Inca Empire. It is tempting to hypothesize that these forecasts date to pre-Columbian times and represent a survival of ancient Andean traditions. Several lines of evidence support this idea. The astronomical knowledge of the Inca was quite detailed, and these people certainly considered the Pleiades to be an important celestial feature. Also, Inca astronomers observed the pre-dawn sky in late June, around the time of the winter solstice, as part of their *Inti Raymi* or sun festival. However tantalizing, these clues do not, of course, constitute proof that this tradition reaches back that far.

A third area of inquiry is the uniqueness of this sort of practice. We are aware of five other cultures that have such beliefs—if we exclude Punxsutawney Phil and his followers. But this figure may underrepresent the actual number of predictive strategies, which tend not to be documented very well. (To help remedy that problem, we have compiled information about these schemes and other traditional knowledge about seasons in a database, which can be consulted by following the link given at the end of the article.) We suspect that with time the scholarly study of indigenous cultures will uncover a far larger number of traditions for forecasting the weather.

To date, there have been only a few tests of such predictions. Purshottambhai Kanani, an agronomist in Gujarat, India, has been examining local beliefs in this regard since the mid-1990s. For the years of his study, the variation in the blooming of the golden-shower tree, *Cassia fistula,* has served well to predict the onset of the monsoon, coming very close to farmers' claims that the flowering peak occurs a month and a half before the rains. Plant ecologists have established linkages between climate variability and the timing of bud break, flowering and other phenological markers, so it is perfectly reasonable that the locals would have noted these connections.

Villagers in Kanani's study region also use atmospheric variability to forecast the monsoons. According to them, north and west winds at the festival of Holi, at the full moon in March, indicate that the monsoon rains, which arrive in June or July, will be sufficient or abundant, whereas east winds at this time suggest that rainfall will be scanty. In the six years for which Kanani collected data, these forecasts proved generally accurate. Although it is far too early to anticipate the fraction of folk meteorological beliefs that are supported by systematic collection of objective data, it seems unlikely that the Andean case is unique.

The final question is the usefulness of the study of such indigenous forecasts. From the perspective of pure scientific research, it is, of course, worthwhile to document people's ability to observe nature's regularities and to modify their subsistence activities accordingly. This capacity, a key component of many cultures, has contributed significantly to making humans one of the most widely distributed species on the planet. Within the field of anthropology, these forecasts form part of the broader tapestry of folk knowledge about the environment, a field of burgeoning interest in recent years.

From the perspective of applied research, the study of indigenous forecasts forms part of the growing network that connects climate researchers, policy-makers, administrators and citizens. The forecasts demonstrate that local populations are not fatalistically resigned to accept climate variability as a harsh reality. Rather, they seek information that they can use to adapt. The strategies they employ give an indication of the lead time required of the forecasts and offer some notion of the climate conditions local people wish to know in advance. This information can help meteorologists prepare useful projections and can improve communication between the producers and consumers of modern scientific forecasts. It may contribute as well to the alternative responses to climate change that are currently being discussed. As close observers of climate variability, local peoples around the world should certainly participate in these debates.

Bibliography

Aceituno, P. 1988. On the functioning of the Southern Oscillation in the South American sector. Part I: Surface climate. *Monthly Weather Review* 116:505–524.

Bauer, B. S., and D. S. P. Dearborn. 1995. *Astronomy and Empire in the Ancient Andes: The Cultural Origins of Inca Sky Watching*. Austin: University of Texas Press.

Garreaud, R. D., and P. Aceituno. 2001: Interannual rainfall variability over the South American Altiplano. *Journal of Climate* 12:2779–2789.

Kanani, P. R., and A. Pastakia. 1999. Everything is written in the Sky!: Participatory meteorological assessment and prediction based on traditional beliefs and indicators in Saurashtra. *Eubios Journal of Asian and International Bioethics* 9:170–176.

Kent, G. S., E. R. Williams, P. H. Wang, M. P. McCormick and K. M. Skeens. 1995. Surface temperature related variations in tropical cirrus cloud as measured by SAGE II. *Journal of Climate* 8:2577–2594.

Liao, X., W. B. Rossow and D. Rind. 1995. Comparison between SAGE II and ISCCP high-level clouds 1: Global and zonal mean cloud amounts. *Journal of Geophysical Research* 100:1121–1135.

Mishkin, B. 1940. Cosmological ideas among the Indians of the southern Andes. *Journal of American Folklore* 53:225–241.

Orlove, B. S. 1979. Two rituals and three hypothesis: An examination of solstice divination in southern highland Peru. *Anthropological Quarterly* 52:86–98.

Orlove, B. S., J. C. H. Chiang and M. A. Cane. 2000. Forecasting Andean rainfall and crop yield from the influence of El Niño on Pleiades visibility. *Nature* 403:68–71.

Rossow, W. B., and R. A. Schiffer. 1991. ISCCP cloud data products. *Bulletin of the American Meteorological Society* 71:2–20.

Salomon, F., and G. L. Urioste (eds.) 1991. *The Huarochirí Manuscript: A Testament of Ancient and Colonial Andean Religion*. Austin: University of Texas Press.

Schaefer, B. E. 1993. Astronomy and the limits of vision. *Vistas in Astronomy* 36:311–361.

Urton, G. 1981. *At the Crossroads of the Earth and the Sky: An Andean Cosmology*. Austin: University of Texas Press.

Vuille, M. 1999. Atmospheric circulation over the Bolivian Altiplano during dry and wet periods and extreme phases of the Southern Oscillation. *International Journal of Climatology* 19:1579–1600.

Links to Internet resources for further exploration of "Ethnoclimatology in the Andes" are available on the *American Scientist* Web site:

http://www.americanscientist.org/articles/02articles/orlove.html