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Cover Artist

Roxanne Chinook is a tribal member of the Confederated Tribes of the Warm Springs Indian Reservation in Oregon. “My art emulates a personal and cultural experience, from the spirit of the trickster to healing from the traumas of my past.”

For more information, contact American Indian Art from the Pacific Northwest, Box 101, Lummi Island, Washington 98262, e-mail: admin1@ebynativeart.com, or (360) 738-0488.
Forecasting the weather is one of the largest areas of research in atmospheric science and certainly one of the most well known. Weather forecasting deals primarily with understanding the weather—the day-to-day fluctuation of the atmosphere—and is concerned with short-term questions like where, when and how much it will rain.

Lacey Holland, Cherokee, grew up in rural Oklahoma. At seven, she saw her first tornado—one that went on to devastate a nearby town. Now an associate scientist at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, she works to produce new kinds of weather forecasts that pilots can use to avoid tornadoes and other kinds of severe weather. “I like working with both data and people,” she says.

Holland is an atmospheric scientist. Her field seeks to understand the atmosphere as part of the Earth’s system and to use that understanding to improve life on Earth. Atmospheric science includes a broad range of research topics, from studying the tiniest processes such as how water molecules are attracted to a particle of dust suspended in the air, to studying how solar flares twice the size of the Sun influence the upper atmosphere of the entire planet. According to Jonathan Vigh, Seneca Nation, a doctoral candidate in atmospheric science, the ultimate goal of atmospheric science is to “understand the complete linkages between weather and climate, human society, and the ecosystems. Hopefully, the science can point to ways to make the entire planet healthier.”
Better Weather Forecasts

According to Holland, people often assume “if you are a meteorologist, you must be on television.” In fact, Holland says, “Weather forecasters work to create timely forecasts of everything from precipitation to severe weather to high and low temperatures. They then work to distribute these to the public.” She gets plenty of good-natured teasing, especially from her husband. “He says it’s the only profession where I could be wrong 50% of the time and still keep my job,” she jokes. “I end up reminding him that a .500 batting average is unheard of in baseball.”

Holland’s job at NCAR focuses on improving weather predictions by providing better tools and knowledge to forecasters. “I imagine probably the most important advances in the next 10 years will involve improving the prediction of extreme weather events. I think there will be extraordinary strides in numerical weather prediction and data assimilation to this end,” she continues, referring to two of the important tools upon which many forecasters rely. Numerical weather prediction uses large computers to predict the future condition of the atmosphere by stepping forward in small increments from current weather conditions. Data assimilation is the process of making sure that the computer registers as up-to-date weather conditions as possible. Holland continues, “As numerical weather prediction models get more and more detailed, I think we’ve got another leap to make in improvements of meteorological observations and data assimilation.”

Seasonal Forecasting

One emerging area of forecasting deals with forecasting weather trends three to four months into the future. These seasonal forecasts allow businesses, industries, agriculture and people to plan over a longer term—to know, for example, if they will need to budget more for heating in a colder-than-average winter. A very important factor in seasonal forecasts is the semi-regular change in the temperature of the ocean surface along the Equatorial Pacific. Known as the El Niño-Southern Oscillation (ENSO), this regional change has impacts all over the globe. A 1995 economic study suggested that better ENSO forecasting could be worth between $100 million and $125 million annually, just in terms of the agricultural impact in the southeastern United States.

Bret Harper, Coast Miwok and Southern Pomo, grew up listening to the surf reports. “I became interested in how storms, sometimes thousands of miles away, could generate these conditions,” he remembers. Harper is now investigating how the influence of seasonal factors, like ENSO, might impact renewable energy sources, as part of his master’s degree work at the University of California, Berkeley.

During the summer of 2005, Harper looked for a correlation between ENSO and long-term variations in wind speed at four locations in South Dakota. The choice of South Dakota is significant because the first utility-scale Native American wind turbine was installed on the Rosebud Reservation there in 2003. According to Harper, understanding the seasonal factors that influence winds “has important implications for those who want to develop more wind farms. Our preliminary results confirm that information on climate variability and change can be of significant use and value to future wind-power planning, siting and performance.” According to Harper, “Now I am exactly where I wanted to be, learning and doing research in the renewable energy field.”

Severe Weather

As a boy, Jonathan Vigh, Seneca Nation, spent a weekend camping in Indiana. During that weekend, the remnants of Hurricane Hugo crossed paths with a late-fall high-pressure system, producing a windstorm that brought down tree limbs in the forest where he was camping. “Experiences like this,” he shares, “cemented my desire to understand what makes the atmosphere tick.” Vigh is currently a doctoral student at Colorado State University (CSU), study-
ing the kinds of storms that influenced his camping trip—hurricanes.

“Each year, about 80 tropical cyclones form around the world,” says Vigh, “and many of these storms cause great upheaval and disruption to society.” At CSU, Vigh studies the hurricane eye—the central region of the storm whose behavior influences how the storm will intensify. “I like the idea of being a hurricane specialist,” he relates, “because I have the opportunity to serve both science and society in a very practical way. If I can contribute to an understanding of hurricanes that leads to better forecasts that can ultimately save lives, then I will have accomplished the mission of my job.”

The science itself offers a unique blend of observation and theory. “Storms seem to live and breathe,” Vigh explains. “To study these beasts requires a different kind of science than some fields—this is a science that involves an active probing of the beast just to get data. Fleets of hurricane-probing aircraft sample the storm, specialized satellites peer down from space, and floating ocean buoys and land stations sometimes survive long enough to send back reports from the surface.” Once the data is collected, it must be integrated with theories. “I love watching the storms during hurricane season—it is fascinating to try to forecast their antics and put theories to the test.”

When he was 11 years old, Erik Noble, Echota Cherokee, remembers picking up debris with his family and other citizens after a strong tornado cut a ten-mile path of destruction through his city. “I knew that I wanted to learn about the weather in order to help protect others from more tornadoes,” he says. Now he is completing his master’s degree at the University of Colorado at Boulder, studying the societal and economic impacts of extreme weather. “During the past year,” he states, “I examined the growth of dam-age trends for U.S. floods in order to provide information about climate and societal factors that will influence future damaging flooding events.”

### Education and Salary

Careers in atmospheric science are available at the bachelor’s, master’s and doctorate levels. A bachelor’s degree in meteorology is the minimum requirement for most beginning jobs, and the average starting salary for someone with no additional experience is between $23,400 and $29,000, according to the Bureau of Labor Statistics.

A master’s degree is necessary for work in research and development, with a starting salary ranging from $35,500 to $42,900.

Independent research requires a Ph.D., with starting salaries averaging $51,500 a year.

According to the American Meteorological Society and University Corporation for Atmospheric Research, more than 100 colleges and universities offer studies in meteorology.

A complete list is available at www.ametsoc.org/amsucar_curricula/index.cfm

### The Changing Climate

Casey Thornbrugh, Mashpee Wampanoag, was a “climate junkie” from an early age. “In middle school, my friends and family would name off a city in North America and I would tell them the average temperature, mean total precipitation, and other climate variables for every month in that city,” he recalls. Today, as a graduate student at the University of Arizona in Tucson, he studies the impact on the population of a changing climate.
“Climatology is the study of weather elements (like temperature, wind, precipitation, etc.) over long periods of time,” Holland explains. “Climatologists address lots of interesting problems from risk management to earth-sun interactions,” Vigh adds. “Climatology looks at the role of the various aspects of physical meteorology,” Vigh continues, “as well as... how these combine to produce the overall climate of a region, like rain forests or deserts, or the entire globe. Of course, one of the major questions currently being investigated in climatology is how the global climate will change as a result of human impacts.” Or, as Harper puts it, “How is climate change affecting us today and tomorrow?” Thornbrugh concurs: “The most important meteorological question is how much climate will change and what will be the impacts on the next seven generations.”

There is considerable evidence that climate is changing, and that the change is due to human influence. Temperature measurements across the globe over the last 150 years show that Earth’s surface air temperature has risen more than one degree Fahrenheit since the late 1800s. In addition, the melting of glaciers, rise in sea level, and changes in migratory patterns of animals and plants suggest a warming planet. Most atmospheric scientists believe that this warming is due to human release of greenhouse gases, especially carbon dioxide, into the atmosphere. And most atmospheric scientists believe it will get worse; the Intergovernmental Panel on Climate Change (see sidebar), which includes more than 1,000 climate experts, predicts that increasing levels of greenhouse gases like carbon dioxide will warm the planet an additional 2.5 F to 10.5 F.

Thornbrugh is in the field of applied climate research, trying to build a connection between climatology and the people who need to use and understand the data. “The present political and social conditions across the globe make the exact impacts of climate change more complex, and these impacts need to be understood in order to plan for the physical and cultural survival of people across the planet,” he believes.

Thornbrugh spent last summer assessing the motions of sand dunes over the Coalmine Mesa chapter area of the Navajo Nation. “This study,” he reports, “was motivated by concerns about indigenous peoples across the globe. Many residents of the Navajo Nation on the southern Colorado Plateau are concerned that the future climate of the region will be warmer and drier than was observed in the 20th century.” One impact of a drier, warmer climate might be increased movement of the sand dunes, which could damage infrastructure and impact agriculture. To approach the problem, Thornbrugh used earlier climate data to estimate the conditions of sand dunes in the past. “This work shows that the index can be used for other areas on the Navajo Nation, to identify locations at risk and help in planning efforts to mitigate effects from climate change.”

Indigenous peoples in the Arctic are already experiencing the effects of the changing climate. According to the Arctic Council, an international organization that includes six international indigenous organizations and eight countries with land in Arctic areas,
“Saami are seeing their reindeer grazing pastures change, Inuit are watching polar bears waste away because of a lack of sea ice, and peoples across the Arctic are reporting new species, particularly insects. Some communities are having to sandbag their shorelines to try to slow down an increase in coastal erosion, while in others, buildings, pipes, and roads are slumping because the permafrost is thawing.”

Other Areas

One area of specialization not touched on in the research described here is atmospheric chemistry. “In atmospheric chemistry,” Holland points out, “the composition of the atmosphere and chemical interactions within it are studied. One of the important topics here is the effect people have on the atmosphere and its chemistry.” Vigh adds, “This sub area seeks to understand why smog forms and the reasons that the ozone layer is being depleted.”

The research of Harper, Holland, Noble, Thornbrugh and Vigh is just the tip of the iceberg in atmospheric sciences. The field includes people from every scientific background: from biologists who can help understand how carbon dioxide is taken out of the atmosphere by plants, to oceanographers who explain the influence of oceans on fluctuations in the atmosphere. The field welcomes engineers and computer scientists to build cutting-edge observation techniques and develop innovative uses of some of the largest computers in the world.

Integrating Many Approaches

To reach its goal of understanding the Earth, atmospheric science integrates knowledge from a wide array of other disciplines. Vigh points out that, “Meteorology and atmospheric science are rigorous physical sciences, but they are also very interdisciplinary in nature.” Harper concurs: “I feel that atmospheric science lends itself to interdisciplinary research easier than other science fields. This has made it easier for me to approach social problems from the quantitative security of natural science.”

For example, one of Harper’s projects involves studying how yearly changes deduced from careful analysis of several decades of wind data provide valuable information for wind energy production and the energy industry in general.

In addition to integrating several disciplines, meteorology integrates many different approaches. “Progress in understanding is made through observations, theory, and modeling,” Vigh says. “Technological innovations like weather radar, environmental satellites and the telecommunications system have certainly revolutionized the field. Many actual discoveries have arisen due to observations, but progress in understanding has often been made through theory and modeling. The whole field often moves lockstep in producing advances, rather than just evolving from a single brilliant insight.”

Bridging Western and Indigenous Knowledge

Innovative atmospheric science research increasingly requires integrating multiple influences into an understanding of the overall system, and Native American students will contribute to a more holistic perspective in the atmospheric sciences. “I think the Native viewpoint or approach to science tends to be more holistic—understanding how everything fits together and what effect each of the small parts has on the others,” Vigh believes. “As Native peoples, we have a unique cultural appreciation of the natural world, and it is perfectly fitting that we be involved in the study of these areas.”

This integration is not without some tension, however. According to Harper, “Atmospheric scientists, like almost all scientists, do not always
Significant Opportunities in Atmospheric Science (SOARS®)

All of the students mentioned in this article participated in the SOARS® program as protégés. SOARS® is an undergraduate-to-graduate bridge program designed to broaden participation in the atmospheric and related sciences. The program is equal parts research internship, learning community, and mentoring program. SOARS® offers comprehensive financial support for summer research and graduate school for up to four years. The program is administered by the University Corporation for Atmospheric Research with headquarters in Boulder, Colorado.

SOARS® invites students from many disciplines, including chemistry, physics, engineering, mathematics, ecology, geography and the social sciences, to apply their expertise to understanding the Earth's atmosphere and related systems, and to use their understanding to improve our relationship with the Earth. SOARS® seeks to involve more students from groups that are historically underrepresented in the sciences, including Latino, Chicano, African-American, American Indian, Alaska Native and Native Hawaiian populations. Since 1996, 98 students have participated in SOARS® as protégés, including 13 Native Americans.

All protégés are invited to spend the summer in Boulder to work with a team of scientists and mentors at the National Center for Atmospheric Research and other Boulder-area labs on a project matching their interests and skills. They perform original research, prepare a scientific paper, and present their research at a colloquium. Protégés are supported by up to four mentors, including a research mentor, writing mentor, community mentor, and peer mentor (a protégé who has participated in the program in previous years).

Protégés are eligible to participate in the program for up to four summers. During the summer, they receive a competitive stipend and round-trip travel to Boulder. They share a townhome with one other protégé and are eligible for additional travel support to present their results nationally. Graduate funding for continued study in atmospheric and related sciences is also available.

For more information, visit www.soars.ucar.edu

acknowledge Native reasoning as science.' Vigh adds, “Much of the approach of Western science involves reductionism—understanding a phenomenon, physical property or concept by breaking it down to separable parts or theories.” But Harper sees the tension as “often just unfamiliarity with a different way of thinking. Native students must remember to step outside their comfort zone to learn what scientists have to offer. As an Elder once told me, you must journey down both paths.”

Thornbrugh offers an example from his own experience: “While beginning my undergraduate education, I utilized mostly Western quantitative research techniques in applied climate studies. Now that I am older, I feel there is much qualitative data which can be found in oral tradition and related to climate change.” Noble concurs, adding, “On many occasions, resorting to a circumferential holistic approach prevented me from getting swallowed in details. In fact, it has often helped me answer the ‘so what’ question for research.”

Keys to Success

Atmospheric science is a strongly quantitative science, and requires a deep understanding of physical sciences, like chemistry or math, as well as strong mathematical skills, including significant amounts of calculus. As Vigh says, “Many areas of the field require lots of math and physical understanding, the ability to use computers to process data and create mathematical models, and the necessity of putting together a ‘big picture’ from all the details.”

Strong quantitative preparation is important and lays the foundation for continued success. To ensure success in atmospheric science as in any field, students need a strong support network and a connection to the work they are doing. Harper advises students “to pursue an aspect of the field that is really interesting and something you can be passionate about. Otherwise, it is easy to get sick of what you are doing as you become more and more immersed.” Holland speaks of the value of a support network: “It’s important to try to form a support system of people who will listen and put everything into perspective for you.” Thornbrugh concurs, adding, “It is also important to stay connected to family for support, as many of the atmospheric science programs offered may be located far from a student’s home community.” Noble emphasizes the value of mentoring by suggesting students diligently seek out a mentor “who not only advises but also actively helps you improve your abilities.”

Perhaps the most important key to success for Native students is to bring the strengths of their cultural heritage to bear on the scientific issues of the day. In the atmospheric sciences, these strengths can guide a shift in the approach to complex environmental problems. With the participation of Native students, the science can move toward a holistic approach that doesn’t flinch from the interconnections in the natural world. Vigh sums it up well, saying, “I feel that Native students have much to offer in the study of Mother Earth and Father Sky.”

In contributing these strengths, Native students are in a unique position to both enhance the science and benefit their communities. Harper advises: “Remember to give back to your communities whenever the opportunity arises. Native students have a unique understanding of the special considerations that have to be taken when working within these communities that many outsiders don’t fully understand.” Thornbrugh adds, “Always keep your family and community informed about what you are working on. This is important because your expertise may be called upon, and it is always a positive situation to be able to work with family and community members on complex, local environmental issues.”

Rajul Pandya is the director of the Significant Opportunity in Atmospheric Research and Science program (SOARS®). Pandya earned his Ph.D. studying the processes that contribute to the organized structure of large thunderstorms.
Suzanne Van Cooten, Chickasaw Nation, wonders if the fact that she was born on February 15, 1968—during one of the worst snowstorms in Oklahoma City history—has anything to do with her passion for meteorology. Her parents and grandparents did instill in her a fascination with and appreciation of weather as they “would take me outside and we would look at the sky, feel the wind, and notice the humidity on a ‘tornado’ day. In the fall, we would go outside and look at the thin wisps of cirrus, ‘mare’s tails,’ high in the atmosphere. From the ‘mare’s tails,’ the color of the sky, and the leaves on the trees, you could tell the first cold snap was coming or if an ice storm was a couple of days away. It was just something you could feel if you grew up here. The weather was something you respected.”

Van Cooten is believed to have been the first Native female meteorologist in the United States. She knew as a child growing up in central Oklahoma “that people could survive tornadoes and weather extremes. What I did not know was why. Were we more prepared in Oklahoma, did we have better buildings, or were we just very lucky? To find the answers to these questions is why I became a meteorologist and a civil/environmental engineer…if we can predict weather and its effects better, if we can design safer structures, if we can keep people from building in disaster-prone areas, if we can communicate these threats better through improved communication and language programs, then we can save more lives.”

Throughout high school, Van Cooten was an avid sportswoman (playing softball, basketball and soccer) and cellist while taking an accelerated curriculum of math, science, and English. She attended the University of Oklahoma (OU) in Norman on an engineering and music scholarship, where she tried out electrical and civil engineering. It wasn’t until her junior year that she discovered her passion for meteorology. She received her bachelor of science degree in meteorology from OU in May 1991.

A Career in Weather Forecasting
Van Cooten has worked for the past 14 years in a variety of weather-related roles at the National Weather Service while also pursuing her master of science degree in engineering and her Ph.D. in engineering and applied science at the University of New Orleans. She has been an operational forecaster, hydrologist, regional program manager, and research scientist with the National Oceanic and Atmospheric Administration’s (NOAA) National Weather Service. She has done everything from preparing advanced forecasts for the public and the aviation field, to forecasting wave height, wind direction and speed as well as visibility for the entire Gulf of Mexico. Van Cooten remembers “the additional forecasting responsibilities of issuing gale, tropical storm and hurricane warnings for the Gulf of Mexico in coordination with the Tropical Prediction Center.” She has also coordinated and forecasted memorable severe weather occurrences including “several tornado and large hail events in North Texas, the Thanksgiving 1992 North Texas ice storm, and Gulf Coast tropical season events including Hurricane Georges (1998) and Tropical Storm Allison (2001).”

At present, Van Cooten works as a hydrometeorologist for NOAA’s Office of Oceanic and Atmospheric Research (OAR) National Severe Storms Laboratory (NSSL) in Norman, Oklahoma. Her research focuses on “historical precipitation patterns and how these climatological patterns, coupled with improved rainfall estimation techniques, can improve streamflow estimation techniques, can improve streamflow estimation techniques, can improve streamflow estimation techniques, can improve streamflow estimation techniques, can improve streamflow estimation techniques.” According to Van Cooten, “Weather affects everything we do and every decision we make, so I thrive on my interesting and diverse career and the wide circle of friends my experiences have given me. I can talk intelligently to an amazing spectrum of people, as weather is a critical factor in commodity trading, agriculture, energy production, sporting events, tourism and public policy. I am a social person and I rely on these skills and networking abilities to get people excited and motivated about the science behind meteorology, hydrology and engineering. What is even more exciting is that many aspects of these fields remain unexplored. The best thing about my job as a research scientist is that I am now in a position to build teams of outstanding professionals with seemingly unrelated areas of expertise to discover the answers to our most complicated issues in water resources and
how we will manage these resources in the future.”

Occupational Hazard

Van Cooten knows that the least desirable aspect of her job is “getting the forecast for a natural disaster ‘right.’” As a hydrologist, you can forecast river stages that will cause catastrophic damage to major metropolitan areas where you live. As a meteorologist, you can predict the area where tornadoes and large hail will develop. As an engineer, you can predict what damage will occur with a hurricane storm surge, winds and inland river flooding. The hardest part is when these predictions come true in an area where you and your loved ones live. As a professional, you must stay and work through these events and work even harder in the aftermath where your office buildings are damaged and your staff has worked long hours. You have to worry about what happened to your family if they evacuated and what is the condition of your home and belongings in addition to providing top-level service and operational forecasts for rescue and cleanup operations.”

Advice for Prospective Students

Van Cooten has some important words of advice for anyone interested in the possibility of a career in meteorology, an area she refers to as “an inexact science.” She relishes the fact that “there are many fascinating questions to be answered. In my opinion, these questions will only be answered if we have a scientific workforce that is as diverse in expertise, thoughts and culture as the multifaceted subjects we are seeking answers to.”

Students heading in the direction of meteorology need to excel in math and science, believes Van Cooten, as well as “have a creative spirit to be able to adapt this fundamental knowledge to a local application or forecasting issue.” Other necessary qualities for succeeding in this field include communication skills. “You also have to be able to communicate effectively to warn people of danger, write a concise and accurate forecast product, author professional articles to document your scientific successes and speak in public forums to your peers, supporters and political advocates,” relates Van Cooten. “I see the most successful scientists as those who are not only credible in their scientific positions, but are also able to deliver their message to a wide variety of audiences.

“I see the geosciences as inextricably linked to the Native American community,” she continues. “The fields of geology, hydrology, meteorology and geography have their historical foundations in the stories passed down through Native American cultures. Native Americans have always been connected to the Earth and its environment. As a student, you can begin to bring these geosciences to your communities and engage Native Americans as our nation’s environmentalists. These programs are needed by both the United States and the Native American communities to provide a fair and equitable leadership role for Native Americans in the design of United States public policy for water resource management and environmental monitoring.”

Future Issues

When asked about her thoughts on the major issues her field will need to address in the future, Van Cooten acknowledges, “As meteorologists and hydrologists, we will have to emphasize the role of the social sciences in our future research planning. One emerging need is the way we will manage water resources. How do we make the choice for the growth of a metropolitan area in a desert region of the southwest United States to the detriment of aquifer recharge and agricultural diversions downstream? Another area is development in disaster-prone areas such as barrier islands, coastlines and floodplains. How do we make an accurate assessment and development decision for these vulnerable areas and account for the needs of people dependent on the water for their livelihood?”

Clearly, the field of meteorology needs a host of passionate, well-trained professionals to address these critical issues that directly and indirectly affect the quality of life of everyone in this country and beyond.”