WIND AND THE WIRES: A HISTORY OF SCATTEROMETRY

BY KATIE OBERTHALER & ASHLEY THOMPSON

Radar Scatterometers take snapshots of the oceans’ winds many times a day from high-flying satellites. They help to measure strong storms, like hurricanes, model global climate, study sea ice, and even navigate international sailing contests. This little-known technology evolved from an even more esoteric history. Before CReSIS scientists flew multi-channel radars over the Arctic and Antarctica, their forerunners were engineering the first scatterometers in space.

In 1965, Richard Moore and Willard Pierson might have been the only two people in the United States who weren’t shooting for the moon. NASA had just successfully sent a man into Earth’s orbit. Four years later, Neil Armstrong would plant the American flag on the rocky surface of the moon. Yet Moore, then a professor of electrical engineering at The University of Kansas, and Pierson, an oceanographer at New York University, were eager to get their feet wet with a new technology: scatterometry.

Scatterometry uses microwave radar techniques to measure wind speeds and directions near the surface of the ocean and earth.

Up until the 1960s, naval ships and floating buoys used radar sensors to detect submarine periscopes and other nearby vessels by collecting backscattering data. Around that time, Richard Moore and three other professors had just founded the Remote Sensing Lab at KU, a predecessor of CReSIS. The group believed that they could harness this backscattering to directly measure ocean wind speed and direction. Because earth-based radars provided limited coverage, the group aimed to launch a system into space.

Up in the Air

In November of 1963, Moore received a phone call from Peter Badgley, a NASA representative who was working on the short-lived Manned Space Science Program. He wanted to pool together various instruments to study the earth on a wide scale.

“Badgley was really the spark that started this whole program of space remote sensing in this country,” said Moore.

Moore joined a team of scientists in Washington, D.C. He convinced the team to base the microwave radar systems at the Remote Sensing Lab. “I said, ‘Oh, we can do it in Kansas!’” Moore remembers.

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Prior to scatterometry, sensors had used radiometry, a passive microwave radar. Although scatterometry provides less detailed images than radiometry, the team thought that a scatterometer would expand the spatial coverage of data collection and enhance imaging radars.

“You don’t want the detailed information if you’re measuring winds at sea,” said Moore. “What are you going to do with 5 meter by 5 meter patches over the whole ocean? You’d be overwhelmed. You want things that cover 10 kilometers or more.”

In 1965, the microwave radar team gave a presentation to the National Academy in San Diego to include a scatterometer on The Department of Defense’s Manned Orbiting Laboratory. The Department of Defense aimed to launch a small, man-inhabited capsule into space to provide surveillance on Soviet Russia and China as well as conduct experimental science tests as a part of the Manned Orbiting Program. Moore hoped the DOD would include scatterometry as one of those tests, but the National Academy did not pick up their proposal.

“They were interested in the moon. Part of our story was that we were going to be remote-sensing the moon, but most of the members of [our] team were interested in looking at the earth, not the moon,” Moore explained.

The Manned-Orbiting Laboratory project never left the ground, folding within the year due to budget problems. However, the project did produce results: Moore remembers coining the word “scatterometry” after his presentation to the National Academy.

“We had been using all these different names for it. I said, ‘Let’s come up with a simple word,’ and that’s what I came up with. And the world seems to have adopted it, because it makes sense because it’s something that measures scattering,” said Moore.

Moore’s next project would make that term ubiquitous among space programs. The Remote Sensing Lab partnered with NASA and the Langley Research Center in 1965 to build a 15 gigahertz scatterometer, one of the first in the world. Building a system at that frequency...
NEW HARDWARE SUPPORTS EXPANDING WEBSITE

BY KATIE OBERTHALER

The CReSIS website received a huge overhaul this past winter, but not without the help of its new strongman - the Wiggins server. CReSIS and NSF wanted to improve the site's usability for both visitors and internal users. To do so, CReSIS tech support installed new hardware to support the changes.

The previous Stone Cracker server ran on four gigabytes of RAM with two dual core processors. In contrast, the Wiggins contains four times as much RAM and four quad-core processors.

HIGH SCHOOL SENIORS RECEIVE A BEHIND-THE-SCENES TOUR OF CRESIS

BY KATIE OBERTHALER

Thirteen high school seniors admitted as top recruits to the University of Kansas' Honors Program for the 2010-2011 school year toured CReSIS facilities on March 1 as a part of a Scholar's Day event. The students participated in a question and answer session with CReSIS glaciologist Leigh Stearns, viewed radar technology in CReSIS labs, and visited with the Knowledge Transfer and Education department. This was CReSIS' first year participating in Scholar's Day.

CReSIS' collaboration with the Honors Program began when Stearns taught a freshman honors seminar course in climate change issues. When students responded well to the class, Sarah Crawford-Parker, Honors Program recruitment officer, contacted CReSIS for participation in Scholar's Day. Parker said the Honors Program hosts these events in conjunction with the Office of Admissions to showcase the range of activities that KU offers to incoming students.

“The great thing about CReSIS is it brings together so many disciplines and subjects,” said Parker. “It was very easy for these students and families to see how this research is relevant and exciting.”

Kristin Barkus, CReSIS Education Coordinator, led the students around the Center. She said students responded especially well to the data processing tour. “They were surprised when we described to them the amount of data on their computer compared to the amounts of data collected from the field. The scope of the data impressed them,” said Barkus.

Thomas Clark, a senior at Lawrence Free State High School, liked learning about the MCoRDS Depth Sounder radar on the tour. “I though the presentation about the ice sheets and how the glaciers are moving was pretty cool,” he said. Clark intends to study engineering at KU next fall after excelling at math and science throughout high school. He decided to attend KU after hearing positive feedback from current students.

CReSIS plans to continue to participate in Scholar’s Day in the coming years to expose more students to similar perspectives.
Tim Nussbaum, a fifth-grade teacher at Lowman Hill Elementary School in Topeka, has worked with Cheri Hamilton for two years and has seen and appreciated the growth of the CReSIS education program during that time.

HOW MANY STUDENTS DOES CHERI SEE REGULARLY AT YOUR SCHOOL?
180 students from seven different classrooms.

WHAT WERE YOUR INITIAL EXPECTATIONS?
I wanted the kids to get an outside perspective on science and to get to do a lot of, their words, "cool" (pun) experiments.

HOW HAVE THE CRESIS LESSONS CHANGED OVER THE LAST TWO YEARS?
They are even more hands-on and discovery-learning based than they used to be. We have had Cheri come ten times this year, which is more than last year. The student log books have grown in size and detail.

HAS YOUR SCHOOL/CLASSROOM BEEN ENGAGED IN CLIMATE SCIENCE PREVIOUSLY?
We talked about global warming and the poles but nothing to the extent which Cheri teaches us.

WHAT IS THE HARDEST CONCEPT FOR KIDS THIS AGE TO GRASP REGARDING POLAR SCIENCE?
That the layers of ice over thousands of years can tell us about the weather on the earth during a given time period. The way in which people in Greenland have to use the bathroom is a close second.

WHAT ABOUT THAT AGE GROUP (FIFTH-GRADERS) MAKES IT AN IDEAL TIME TO TEACH THEM ABOUT GLACIERS AND POLAR RESEARCH?
They have always loved science and enjoy learning about the world around them. They are realizing every choice they make has positive or negative consequences. This helps them want to take care of the earth and everything in it so future generations can have clean water and glaciers.

On February 13, 2010, Cheri Hamilton joined over 25 area science educators presenting at Kansas City’s annual ScienceWise Teacher Resources Day. Held at the University of Missouri Kansas City campus, the event was designed to expose area teachers to new and innovative ways of teaching science to young learners.

Hamilton, the K-12 Education Outreach Coordinator at CReSIS, was at the helm of her always-popular Glacier Goo table, and also provided hand-out materials to interested teachers. She said she was encouraged by seeing so many familiar faces, those of educators who had attended Teacher Resources Days in the past. This was her third year presenting at the event.

“Teachers from previous years were still wanting new ideas for their science classrooms,” Hamilton said. “They also reported that they had used our Ice, Ice Baby activities with great success.”

Along with Master Teachers presenting their science lessons, over 35 science-related organizations also came out to share opportunities available to schools and teachers. An estimated 130 teachers attended the event, many of whom were pre-service teachers from surrounding colleges, Hamilton said.

“They were all enthusiastic and thirsty for teaching ideas for their classrooms even in an economy that they may not be hired in,” Hamilton explained. “Many hoped to be able to use the simpler Ice, Ice Baby activities when they were substituting for science classes.”

Family science night at Whittier Elementary in Kansas City, KS on April 13
CRESIS STUDENT ORGANIZATION HOSTS NEW SEMINAR SERIES

Cartoons and climate change kicked off CSO’s first ever lecture series, entitled “Communicating Science.” Four speakers addressed students and faculty this semester on topics ranging from handling graduate student life to creating interactive science websites. Two speakers will round out the series this summer.

KEES VAN DER VEEN
Professor of Geography, University of Kansas

“IPCC WG2 and the Decline in the Public’s Trust in Climate Science”

“There exists this anti-science syndrome. People relate better to someone they can identify with. If you (scientists) can tailor your talk to your audience, it will be the first step in fixing some of the communication failures we’ve seen.”

JORGE CHAM
Cartoonist, Piled High and Deeper

“The Power of Procrastination”

“Get out of your comfort zone. You get more used to explaining your research to others. Get out of that bubble.”

KRISTINE BRUSS
Assistant Professor of Communication Studies, University of Kansas

“Public Speaking for Scientists and Engineers”

“To be a good presenter you need to have a design mentality. Good public presentations are the result of intentional design just like good research is the result of intentional design.”

JANE STEVENS
Director of Media Strategies, The World Company

“Jurnos and Science Journalism”

“The best thing a scientist can do is engage the public. The more familiar you are to the public, the better.”

WIND AND THE WIRES CONTINUED:

was just a theory at the time. The U.S. Navy had demonstrated that backscattering could only measure light winds up to 15 knots. Badgley, along with Moore and Pierson, thought they could push those limits.

Linwood Jones supervised the project at Langley. Jones, now Director of the Central Florida Remote Sensing Lab, said the group did not fold in the face of theory.

“We wanted to take good ideas that weren’t ready for space flight and develop them to fly on future satellites,” said Jones. “We were solutions looking for a problem.”

Jones helped Moore and Pierson test their scatterometer. Under the Advanced Applications Flight Experiment, they tested the scatterometer on a NASA C-130 flying over the Gulf of Mexico. Their testing blew the U.S. Navy’s data predictions out of the water. Moore and Pierson demonstrated that the system could actually measure strong storms.

Around the same time as these tests, the scatterometer finally saw its maiden voyage into space. The Langley Research Center helped NASA launch the Ku-Band Seasat scatterometer in 1978, only to have a technical malfunction truncate its operation prematurely. However, its six-month tenure demonstrated that Synthetic Aperture Radar (SAR)-specific scatterometers could detect ocean wind vectors. Seasat provided the first global coverage of those wind vectors.

A flurry of European and American scatterometers in the 1980s and early 90s continued to add antennas and improve beam movement to cover wider areas multiple times. The longest-operating scatterometer was launched in 1999 from NASA’s Jet Propulsion Lab. The 13.4 gigahertz SeaWinds Scatterometer aboard the QuickScat satellite operated until just last year when the mechanism rotating its antenna stopped working. SeaWinds lasted seven years longer than anticipated and gathered oceanographic and atmospheric data on 90 percent of the world every day.

Scatterometers have helped meteorologists pinpoint and predict the location and dynamics of cyclones, hurricanes, and basic weather fronts. As scatterometry’s global tracking expands, so does its...
“The scatterometers have revolutionized weather forecasting,” said Jones. “If you want to predict weather, it is a global phenomenon. Scatterometry provides a fourth of a million observations per day. It uniformly samples the globe.”

Specifically, QuickScat allowed weather forecasters to create a new wind category called the extratropical cyclone hurricane force-wind. Cyclones in the North Pacific and Atlantic Oceans can reach large scales in the winter time and pose hazards to both commerce and livelihood. Scientists have long known that these storms could produce destructive, hurricane-like winds that intensified quickly. However, they did not possess solid data for their frequency or intensity in these areas of the globe before QuickScat. The monitoring of these winds will now help forecasters predict and track these bursts of wind.

Scientists have also noticed that wind can play a role in ocean upwelling, which can bring nutrients to coastal regions and supports marine biodiversity. Wind data is also used to inform commercial fishing endeavors and offshore oil production. As such, studying the interactions between ocean winds and the water cycle may help scientists map important evaporation and absorption dynamics in the ocean.

Paul Chang leads the ocean winds science team at the National Oceanic and Atmospheric Administration (NOAA). His job demonstrates that scatterometry doesn't necessarily cater exclusively to the meteorological crowd. He has received requests for QuickScat data sets from all kinds of groups.

“I've gotten various emails from different folks interested in putting in wind farms. The level of detail that they look at some of this data is very impressive,” said Chang.

Perhaps the most adventurous use of scatterometry comes from the international sailing community looking to dodge dicey waves and stiff competition in the Southern Ocean. A Global Challenge Around-the-World sailing race team used QuickScat data to find optimal winds and to understand a cold front they encountered near Brazil. SeaWinds also helped the 2008 Beijing Olympic organizers prepare for sailing events in Qingdao, China.

Eye on the Ice

When Dr. Moore and his colleagues invented scatterometry in 1965, they did not imagine that their creation would be counseling regatta fleets. Yet, just as KU’s electrical engineering efforts have tended toward ice sheet studies, so has scatterometry’s applications. Its sensitivity to liquid water’s motion and behavior makes it a valuable instrument in glacier studies. Dr. David Long, director of BYU’s Center for Remote Sensing, has long been applying scatterometry to polar ice sheets.

“Those areas where water percolates back into snow where it refreezes - we call them ice lenses. They increase backscatter, so we can see where melting has occurred and when using data dating back to the early 1990s that map spatial extent of melt in Greenland, said Long.”

Applications for this technology extend far beyond the Poles. BYU currently hosts the largest database for iceberg measurements in the world. Since the early 1990s, radar scatterometry has tracked the movements of large icebergs every single day. The National Ice Center drew on data from QuickScat when it operated. Since QuickScat’s flame went out, Long, BYU and other interested institutions have turned to the European Space Agency’s A-Scat and its polar ice applications for data. Currently-orbiting systems record Arctic and Antarctic ice data twice a day.

The demise of QuickSCAT leaves the status of American scatterometry in limbo. Systems like ASCAT and OceanSat-2 provide some of the coverage that QuickSCAT previously captured. NOAA is pursuing a collaboration with NASA and the Japanese Exploration Agency to launch a dual frequency scatterometer by 2017. The new scatterometer will employ both Ku-band and C-band radar to estimate wind and rain phenomena simultaneously. Previously, rain events have contaminated wind measurements. This dual frequency could also broaden coverage and provide a different depth of snow penetration.

Scatterometry is one field that clearly doesn’t suffer from having too many hands in one pot. Broader coverage and international collaboration will continue to improve weather models worldwide. As ice and climate patterns shift, an armada of international scatterometers will only uncover more phenomena to study.

It’s proven very useful, and looking at ocean winds and sea ice applications as the Arctic region opens up more for commerce and exploration. Scatterometry will be useful for looking at the ice and the wind at the same time,” said Chang. “At those high latitudes, you'll have a lot of repeat coverage. There’s a lot of overlap near the poles.”

Chang also said that NOAA hopes to employ scatterometry to study fluxes in global heat transfer and ocean circulation in the future.

The uses for scatterometry have skyrocketed since Moore offered to develop it at the University of Kansas. Moore, now a professor emeritus of electrical engineering at KU, still contributes to CReSIS studies. Although scatterometry is no longer practiced just by Kansas scientists, Moore’s efforts proved that there is still plenty to study right here on Earth. **

Story Sources:

Scatterometry’s sensitivity provides a better understanding of melting areas by pinpointing where the melt water has percolated back to snow. This photo demonstrates a 15-day time lapse of melting in Greenland in 1999. Photo credit: NASA/BYU
John Paden, former CReSIS graduate student, published an article in the January 2010 edition of The Journal of Glaciology. The article, entitled “Ice-sheet bed 3-D tomography,” outlined the use of Synthetic Aperture Radar (SAR) imaging at Summit Camp, Greenland during a 2005 trip. Paden and his colleagues used the ground-based radar to measure basal conditions and internal layers in an area between two ice core drilling sites at that location.

The study demonstrated foremost that SAR technology could penetrate thick ice. The radar used an eight-channel cross-track array and pulse compression, a novelty above the 2D monostatic SAR radar previously used. 2D monostatic SAR clumps the scattering data in a way makes discriminating between points in the ice difficult.

“Previously, I was looking at a 2D view of the world,” said Paden. “We’d like to have a much bigger aperture. If you have targets that aren’t moving very fast, you can take a bunch of images. Now we transmit a pulse that has a lot of bandwidth. We’re able to discriminate some targets from others.”

The cross-track aperture array added dimension and detail to the data. 3D SAR imaging enlarged the aperture and created a more directed beam of radar signal. A larger aperture and a tighter beam means that the team can distinguish better between targets and mine out fine images from the piles of signals returning from the ice. Paden and his team accomplished this by adding more antennas and receiving channels in the radar array. They also used a bistatic radar setup in which the transmitter and receiver were not combined near one another.

Paden also said this mission was the first attempt to use side-looking SAR radar through thick ice. Previous systems ran in an altimeter mode, which gathers data along a single track of motion. The new array allowed the engineers to steer the radar beam to the left and right, gathering data from a wider sheath of ice. “The side-looking setup allows us to generate an image, like a camera,” explained Paden. Overall, this structure gives the scientist more control over antenna placement and directing the radar beam.

The team also used the unique method of employing the 3D Tomography method algorithm to process the SAR data. This allowed them to produce high-resolution images of the ice sheet’s bed. After collecting the data, they “geo-coded” it by placing it within geographic coordinates. They also folded in information from the dielectric profile of the ice, including ice density and permittivity. Tomography processing then produces a topography map of the side-looking data. From that compilation, a digital elevation model (DEM) mosaic image stitches together grids of lines covered by the radar. The result shows clear, nuanced illustrations of the bedrock’s height.

Paden, who received his bachelor’s degree in computer science as well as his masters and PhD degrees in electrical engineering from the University of Kansas, took three years off from research to work for the Vexcel Corporation before publishing his results. He began compiling the article in July of last year and submitted it to the journal in October. “It was definitely one of those things I knew could be published, but I thought it was just going to slip away. It was satisfying. It leveraged all the work we had done for years,” says Paden.

The publication coincided with Paden’s return to CReSIS. As of this year, he is leading the signal processing efforts at CReSIS. He will work with students to help write the software to process data.

“Since my undergraduate and graduate years, I’ve always wanted to do academic work. I’m so happy to be doing this again. In a lot of different ways I feel passionate about it in the effect you have on the students and the work itself,” Paden said.

Paden will have to adjust to the changes at CReSIS since his student work with engineering professors. An interest in wireless communication led him to enroll in microwave remote sensing classes before CReSIS became a certified NSF Science and Technology research center. Paden especially lauded the increase in field programs, advances in antenna technology and radar systems, and improved cross-discipline dialogues since his student days.

I’m so happy to be doing this again. In a lot of different ways I feel passionate about it in the effect you have on the students and the work itself,

- Paden

“Involvement with the glaciology community still happened, but at a lower level. It makes a difference to have people here in the Center who use the data,” he said.

Paden said a continuing challenge for him will be his commute: Paden currently resides in Boulder, Colorado with his wife and three young children. He will work remotely from his home and travel to Kansas once a month.

An even bigger challenge? Remotely sensing rough, crevassed glaciers with SAR radar. Paden hopes that future versions of SAR and 3D Tomography can determine glacial movements.

“Something that would be interesting would be to look at the position of targets in the ice with a radar system, and then fly that radar a month later and look at how much that target within the ice is moving,” he said.

For now, Paden and his team are working to determine the basal conditions from the DEM mosaic images. Like the glaciers, they inch towards understanding a few terabytes at a time.

3D Tomography produces maps of bedrock heights and characteristics. The black dots represent ice core drilling locations.

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Ground-breaking Radar Design

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By Katie Oberthaler
Dan Wildcat, a Yuchi member of Muscogee Nation, began his partnership with CReSIS in June 2006. This marked the first time the American Indian and Alaska Native Climate Change Working Group convened, at a meeting entitled “Ice Symposium: Impacts of a Changing Environment for American Indians and Alaska Natives.” Attendees of this three-day meeting included not only tribal college administrators and professors, but also representatives from federal agencies and national scientific labs. All emerged with hope. Opportunities from the working group, which now meets twice annually, have included student internships and collaborative research efforts between federal agencies and tribal colleges.

“To me, finding these shared interests is the embodiment of how we wanted things to work,” Wildcat said.

Most recently, the group collaborated in planning the second Native People, Native Homelands workshop, which was held in November of 2009, two weeks prior to the COP15 conference in Copenhagen. This workshop represents an effort to foster ways for Native peoples worldwide to have a role in the development and direction of climate change policy. The unique ties that native communities have had with their homelands for generations is why their knowledge should not go ignored in political or scientific arenas, Wildcat said.

“I feel there’s beginning to be a genuine recognition that people who’ve lived in a place for many generations, and people who view their lines as connected to homelands that their grandparents, great-grandparents, children, and children’s children have and will depend upon, possess this longitudinal empirical database,” Wildcat said. “This is something that scientists are beginning to recognize as very important in understanding climate change and adaptation strategies.”

Along with providing a richer understanding to the complexities of climate change, bringing indigenous knowledge into the understanding of the general population may also serve to localize the climate change scenarios. “We know that climate change will manifest itself in very different ways in different places,” Wildcat said. “This is what local indigenous knowledge can give us -- insight and recognition that it’s not one-size-fits-all solutions that will work for us.”

Dan Wildcat’s latest book “Red Alert!: Saving the Planet with Indigenous Knowledge,” calls for a convergence of cultures to address climate change issues.

This indigenous knowledge, or “indigenuity,” as Wildcat prefers, comes less from the interpretation of the human minds, and more from the source itself -- the plants, animals, seascapes, and landscapes that Native Americans and indigenous peoples throughout the world depend upon for their survival. During his presentation to IGERT, Wildcat explained that following one of the working group meetings, a researcher from Northwest Indian College brought up the impact that climate change is having on salmon fisheries, which are one of the main economic lifelines for tribes in the Pacific Northwest. Collaboration between the college and a federal agency ensued, and out of the situation emerged a statement that sums up precisely the experiential, natural essence of indigenous knowledge. “It’s not our knowledge, it’s what the salmon is telling us,” Wildcat relayed to his audience.

“That’s one advantage of indigenous knowledge systems,” Wildcat said. “We typically do not pay attention to what the water may be telling us, to what the salmon may be telling us, but if you begin to kind of rearrange the perspective, you soon realize that the bird, the plant, and its shifts in behavior, may tell you something. It’s not human-centered knowledge.”

Wildcat says he’s certainly not one to contest modern science and the advantages of sound, empirical knowledge. Regarding both experimental and experiential (indigenous) knowledge as essential to understanding the changes the Earth is facing, will lead to a fuller, richer picture of climate change. “Having both knowledge systems in a dialogue is so important because in so many cases, they are complementary.”

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**Photo by: Cameron Lewis**