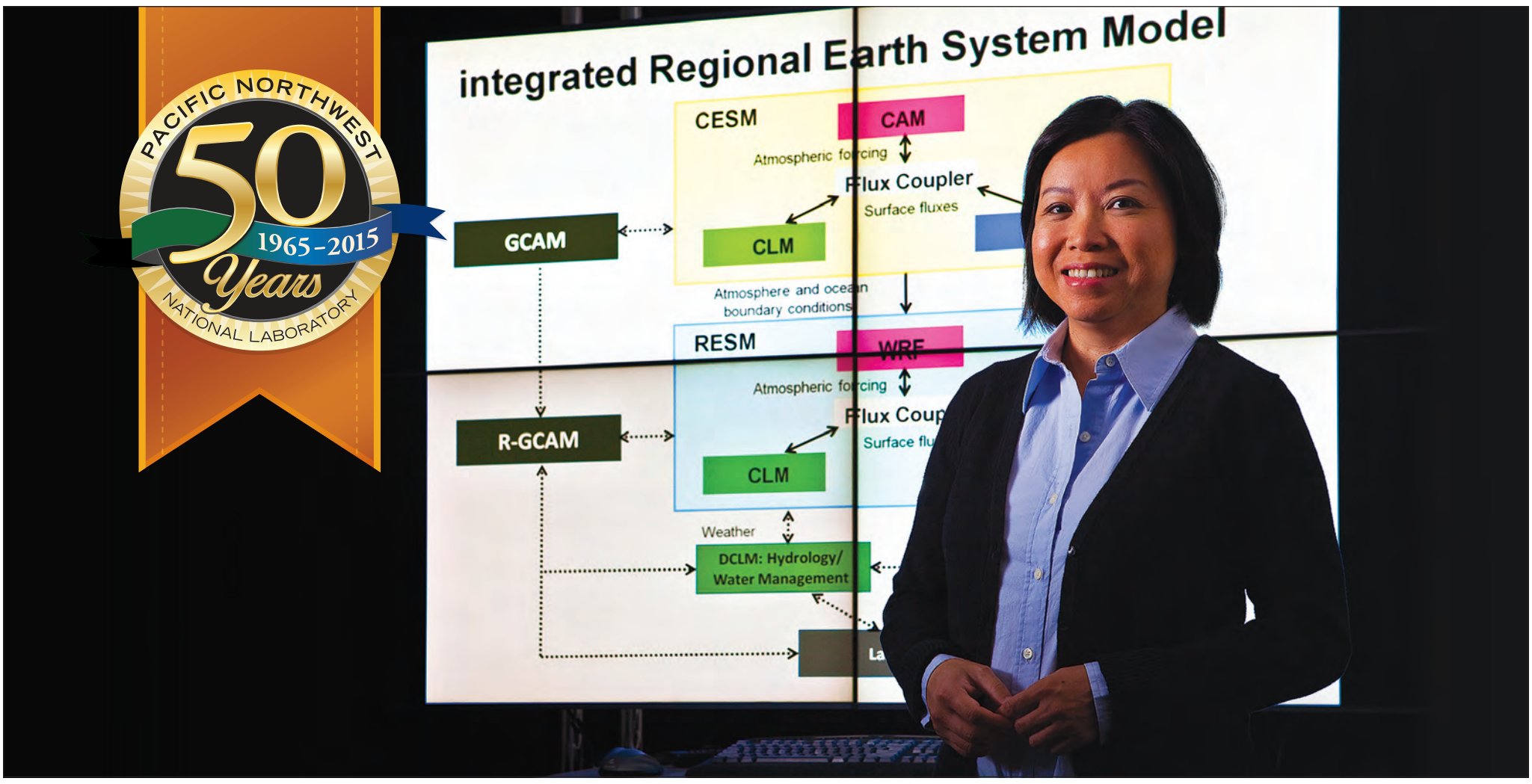
DISCOVERY IN ACTION



Ruby Leung and other Pacific Northwest National Laboratory researchers are expanding the frontiers of atmospheric and climate science by combining advanced modeling of climate and human systems with measurements and high-performance computing to build an understanding of how human and natural systems interact. They work across disciplines to integrate theory, measurements and computational modeling at the molecular level up to the global scale. Here, Leung demonstrates PNNL's Platform for Regional Integrated Modeling and Analysis, or PRIMA, which provides the adaptive framework for significant insights into the implications of different options for mitigating and adapting to climate change.

A closer look at climate

This is the last of a 12-part series that has featured some of the scientific challenges PNNL has tackled over its 50-year history and highlights its vision for the future. PNNL is one of 10 national laboratories overseen by the U.S. Department of Energy's Office of Science and has been managed by Battelle since its inception in 1965. Through this enduring partnership—and by working closely with sponsors and collaborators—PNNL builds upon its legacy to advance science and solutions that improve the lives of Tri-Citians and people around the world. This edition focuses on PNNL's research that is helping build an understanding of underlying processes of atmospheric science and climate science and their potential impacts.

PACIFIC NORTHWEST NATIONAL LABORATORY

This summer's unusually high number of days over 100 degrees, widespread water shortages, ravaging wildfires and poor air quality have been an eye-opener to how changes in weather and climate can impact our lifestyles and livelihoods.

Understanding and predicting potential climate changes and their impacts—with all of the underlying processes as well as variables in cause and effect over time and around the planet—is a huge scientific challenge. The Department of Energy's Pacific Northwest National Laboratory conducts basic and applied research at the cutting edge of this critically important issue.

In a recent project, PNNL researchers focused on understanding and modeling the fundamental processes that govern the variability and extremes in precipitation in the western United States. Their efforts were aimed at improving climate models and the ability to predict the regional water cycle, including floods and droughts.

Considering that the western U.S. receives most of its precipitation during the cold season and that the snowpack accumulated during winter storms provides about 70-90 percent of the water supply for the region, being able to predict fluctuations in the amount of precipitation and when it may come will help better prepare for and mitigate their impact on water availability.

"From an environmental perspective, climate change has emerged as one of our world's most serious challenges," said Charlette Geffen, who leads PNNL's atmospheric science and global change division. "Our expertise in the scientific, technical and socioeconomic aspects of climate change research provides accurate, comprehensive information for regional, national and global analysis to help inform decision makers and shape climate strategies worldwide."

Foundational research

Today's atmospheric science builds upon work done decades ago in support of the Hanford Site. PNNL scientists led some of the first research to determine the impacts of a potential radiological release.

They relied upon a meteorological station at the site, along with the Hanford Diffusion Grid—a 120-meter tower surrounded by concentric arcs of instruments that measured how the concentration of harmless gases released during experiments would change as they were dispersed by the wind—and gained new understanding about the fate and transport of a potential radiological release.

Through this effort, researchers developed computational models and gained a fundamental understanding of boundary layer physics, or the interactions taking place within the blanket of atmosphere closest to Earth where all life lives and breathes, that also has to be accounted for in today's climate models.

Energy and the environment

The early Hanford research expanded to include atmospheric studies in terrain more complex than eastern Washington's flat, open surroundings and was applied to understand the impacts of the power industry, such as extracting shale oil, on the environment.

In the late 1970s, researchers at PNNL started sampling and analyzing pollutants from industrial centers, including carbon gases from coal-fueled power plants, using an aircraft's onboard equipment. They wanted to understand pollutant concentrations and transformations in the atmosphere to better develop regional air pollution models that would help determine the environmental impacts of burning fossil fuels.

PNNL researchers also led a ten-year national program that began in 1980 to determine the causes and effects of acid rain. Building on this research, PNNL has engaged in many national programs to better understand the chemical mechanisms behind the formation of ozone, other secondary pollutants and aerosols that affect human health and climate.

Today, PNNL provides assessments that take an integrated look at economic, physical and ecological systems to explore the consequences of the interactions between humans and the climate system under various scenarios, exploring how to stabilize greenhouse gas emissions and develop strategies to mitigate the impacts of climate change.

Building better models

PNNL's collaborative and integrated approach is facilitated by the broad range of scientific expertise in multiple disciplines all residing within the same organization. In fact, PNNL researchers pioneered the concept of integrating measurement with models, bringing together laboratory experiments and field observations into models to get the maximum value of both.

Researchers are developing and improving predictive climate models that build on their understanding of the underlying atmospheric processes and their interactions with the water cycle, land surface and human decisions. At the regional level, they are looking at short-term and long-term timelines to better understand the impacts of climate change, such as predicting how the Northwest's snowpack and watersheds will be affected over time. Some projects focus on defining very detailed processes that are part of larger models to significantly improve their accuracy.

More than 20 years ago, researchers at PNNL developed the first computational model that used an integrated energy-economic framework to estimate future greenhouse gas emissions. The Global Change Assessment Model divides the world into 32 regions and looks at five-year time steps to examine long-term changes in the interrelated energy, agriculture and land use, and climate systems. Today, it is available to scientists and policy makers around the world.

PNNL also contributed to the Community Earth System Model, which is used by numerous international climate assessments; the Accelerated Climate Model for Energy, a new climate model designed to take advantage of next-generation DOE supercomputers; and the Weather Research and Forecasting model, which can simulate local to global atmospheric processes.

A computing challenge

Understanding climate change and atmospheric science requires scientists to look at these challenges from the molecular level to the global scale, generating and analyzing tremendous amounts of data. DOE's investments in high-performance computing have been critical to advancing this research. New mathematics, innovative algorithms, more sophisticated testing and more complex modeling will bring increasing levels of accuracy.

Collecting climate data

DOE's Atmospheric Radiation Measurement (ARM) Climate Research Facility allows researchers around the world to study the interactions among clouds, aerosol particles and energy feedback processes in the atmosphere by providing access to cutting-edge instrumentation that gathers massive amounts of climate data. PNNL provides the technical direction and operations oversight of ARM, along with contributions from eight other DOE national laboratories.

Through ARM, instruments and equipment at three primary locations representing a range of climate conditions are used by scientists to obtain long-term measurements to characterize how atmospheric properties evolve and to evaluate models under different meteorological conditions. Archived data from a fourth location and field campaigns from around the world are freely available to researchers as well.

A research aircraft owned by Battelle and operated by PNNL is used to conduct ARM campaigns for studying clouds and aerosols and linking aerial measurements with ground-based instruments.

Informing decisions

A group of PNNL researchers also are part of the Joint Global Change Research Institute (JGCRI), an organization formed in collaboration with the University of Maryland in 2001 to investigate the scientific, technological, economic research questions raised by different strategies to deal with the causes and consequences of global change. The institute has provided input to the White House, Congress, the United Nations and national and international advisory bodies.

Leading the future

More than 20 PNNL scientists have contributed to the global efforts of the Intergovernmental Panel on Climate Change, which was recognized in 2007 with the Nobel Peace Prize along with former Vice President Al Gore. Since the IPCC was created in 1988, PNNL's scientific leadership has helped shape all five of the organization's assessments of the impacts associated with climate change and the technological, institutional and policy options available to mitigate and adapt to it.

By collaborating with other national laboratories and universities, PNNL tackles even larger problems and helps others in their research. The Atmospheric Measurements Laboratory at PNNL allows teams of collaborators to access a specialized facility and partner with senior scientists to seek answers to some of the most important questions in atmospheric chemistry and understand how atmospheric particles form clouds.

"PNNL has the people—from leadership in senior scientists to early career scientists with fresh ideas and innovations—that allow us to make significant contributions in this field," said Allison Campbell, acting associate laboratory director for PNNL's Earth and Biological Systems Directorate. "Our science is grounded in the past, but we are leading the future of understanding and solving environmental and climate challenges that face this nation and the world."

Owned by the U.S. Department of Energy; operated by Battelle; and supported by academic, industrial and governmental collaborators, Pacific Northwest National Laboratory is celebrating 50 years of inspiring and enabling the world to live prosperously, safely and securely. Interdisciplinary teams at PNNL address many of America's most pressing issues in energy, the environment and national security through advances in basic and applied science. With an annual budget of about $1 billion and nearly 4,300 staff members, Battelle is the largest employer in the Tri-Cities.

Learn more about PNNL at **www.pnnl.gov** and through stories to commemorate 50 years of scientific discovery contributed by employees, retirees and the community at **www.celebrate.pnnl.gov**.

In 1980, researchers at PNNL led a national program designed to determine the causes and effects of acid rain. The DOE study was part of a 10-year National Acid Precipitation Assessment program, the most comprehensive effort at that time on the acid rain problem.

PNNL offers a state-of-the-art Aerosol Test Chamber located in the Atmospheric Measurements Laboratory to study the aerosol lifecycle. The glow, generated by ultraviolet lights, simulates the sun. Data derived from experiments using the chamber will be used for model validation and incorporated into climate models developed by PNNL.

PNNL operates a Gulfstream-159 twin turboprop aircraft as an airborne atmospheric research facility for DOE and other users who are interested in measurements to better understand aerosol and cloud interactions. Scientists also have used the high-tech instrumentation on this plane and other research aircraft to collect samples from various events, including the eruption of Mount St. Helens, the Chernobyl nuclear accident, the Kuwaiti oil fires during the Persian Gulf War and Washington wildfires.

PNNL researchers are conducting tests on research buoys being deployed to better predict the potential of offshore wind for producing power. These and other fundamental studies being led by PNNL support DOE's goal to make wind energy fully cost-competitive with other energy technologies. In the 1980s, PNNL created the first national wind atlas that mapped the wind energy resource for the U.S., which built upon its expertise in conducting atmospheric studies in complex terrain.