

Confronting Climate Change

How PNNL advances solutions through integrated Earth system science



Confronting the world's changing climate calls for a multidisciplinary approach to understanding how the world, its people, and all other organisms interact and respond to each other in a dynamic, multiscale Earth system. As a decades-long international leader in Earth systems science, PNNL **integrates field and lab observations with modeling and advanced computation to understand and enable a more effective response to environmental change.**

PREDICTING EXTREMES FROM ATMOSPHERE AND WATER CYCLE RESEARCH

PNNL scientists have made seminal contributions to **understanding how atmospheric aerosol particles influence Earth's radiation budget.** We make extensive use of data collected by the Biological and Environmental Research (BER) **Atmospheric Radiation Measurement (ARM)** user facility to understand and model the complex interactions among aerosol, cloud, precipitation, and land surface processes, while our modeling programs in **water cycle and climate extremes** focus on enhancing the predictive understanding of how storms and atmospheric circulation patterns interact and change over time.

PNNL provides **predictions and observations of extreme events** using expertise in data and geospatial sciences, coupled with hydrology, high-performance computing, and emerging cloud-based computing technologies. Observational campaigns leverage **measurement systems and high-resolution modeling** at mobile and fixed ARM sites, the ARM Aerial Facility, laboratory studies conducted at the **Environmental Molecular Sciences Laboratory (EMSL)**, another DOE-BER user facility), and the Atmospheric Measurements Laboratory. Earth systems research at PNNL spans a wide range of critical climatic processes and regimes, enabling important contributions in the increasingly high-priority **Arctic region.** The scientific data and models resulting from this research are applied in an operational context to **support FEMA and the Department of Homeland Security's response to extreme events.**

UNDERSTANDING ECOSYSTEM RESILIENCE AND RESISTANCE MECHANISMS

PNNL's biogeochemistry research program examines coupled hydrologic, geologic, and biological processes, exploring the **role of microbiomes and hydrobiogeochemistry** in the environment to enable accurate predictions of ecosystem resistance and resilience to environmental perturbations. Our research investigates the complex effects of changing conditions on subsurface microbial communities and deepens our understanding and mechanistic representation of river corridor processes from molecular to watershed scales.

PNNL researchers also contribute to the **Next Generation Ecosystem Experiment – Tropics**, recently showing that the world's forests are getting younger and shorter due to anthropogenic changes in climate and land use. EMSL's 10-year strategy includes the creation of a national **Molecular Observations Network (MONet)**, which will build expertise and partnerships to deepen our understanding of molecular and mechanistic processes and their functions within broader environmental contexts.

DELIVERING SOLUTIONS THROUGH MODELING

PNNL delivers advanced predictive tools and results that reflect the **dynamics and interactions of natural and human systems** to inform decision-makers and communities, enabling them to evaluate options and determine strategies for resilience and mitigation of climate change. PNNL's leadership role and significant scientific contributions to the development of sophisticated predictive models, such as DOE's **Energy Exascale Earth System Model (E3SM)**, enable simulation of the intricate connections between energy, economic, and environmental systems to evaluate potential impacts of alternative climate mitigation solutions and related policies. New versions of these models include emerging technologies related to energy generation and distribution, building efficiency standards, and alternate modes of transportation, among other sectors. The Integrated MultiSector MultiScale Modeling research thrust examines **multisectoral interactions across a wide range of spatial (urban to regional) and temporal scales**. This program uses a variety of high-fidelity models to project changes in system vulnerability and resilience to changes in climate, population, and technology advances. For example, PNNL researchers showed how building energy consumption in the Western United States might change under different climate and population scenarios. Other models derived from the Global Change Intersectoral Modeling Systems project allow **simulation of human-Earth systems from continental to global scales** in a consistent modeling framework that supports scenario analysis and discovery.

New projects—Coastal Observations, Observations, Mechanisms, and Predictions Across Systems and Scales (COMPASS) and Integrated Coastal Modeling (ICoM)—bring PNNL's integrated approach of **linking observations, modeling, and iterative experimentation to coastal regions**, which are increasingly under assault by the combined effects of sea level rise, stronger storms, shifts in land use, and other influences. As just one example, PNNL is leveraging agent-based models to understand how coastal development patterns are modifying coastal flood risks.

In summary, **PNNL's capabilities in science-based multisectoral human-Earth systems modeling provide decision-makers with a powerful capability to evaluate and prioritize investments and programs that address multiple policy-related goals and outcomes simultaneously**. Being able to objectively weigh the ramifications of decisions made in the context of complex, coupled human-Earth systems positions the United States to develop effective climate mitigation and resilience strategies that also meet our nation's energy and environmental equity objectives.

ABOUT PNNL

Pacific Northwest National Laboratory advances the frontiers of knowledge, taking on some of the world's greatest science and technology challenges. Distinctive strengths in chemistry, Earth sciences, biology, and data science are central to our scientific discovery mission. PNNL's research lays a foundation for innovations that advance sustainable energy through decarbonization and energy storage and enhance national security through nuclear materials and threat analyses.

CONTACT

Malin M. Young, Associate Laboratory Director, Earth and Biological Sciences
(509) 375-6616 | Malin.Young@pnnl.gov | www.pnnl.gov/earth-system-science,
www.pnnl.gov/capabilities/climate-change-science-atmospheric-science