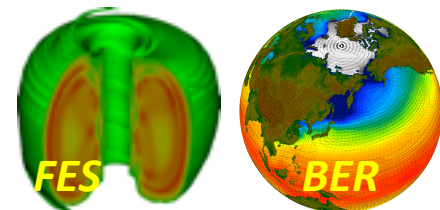
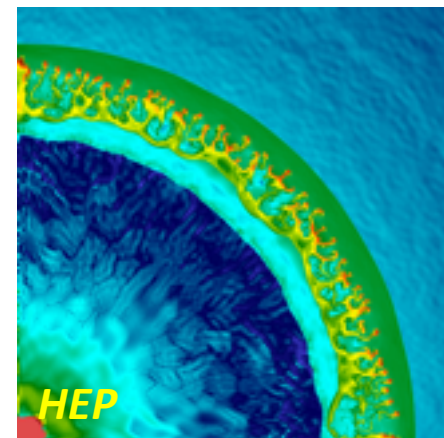
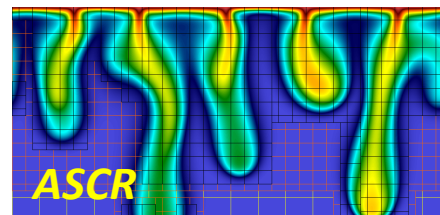
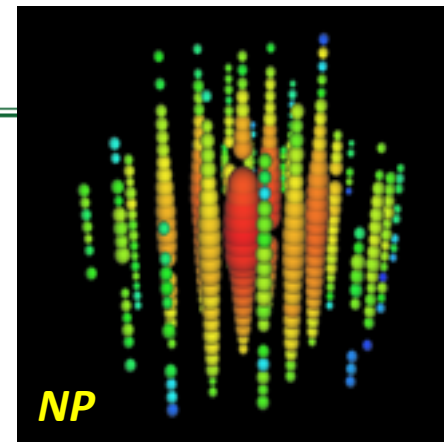
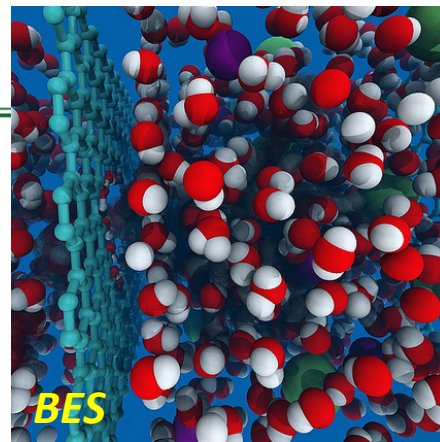


# NERSC Science Highlights



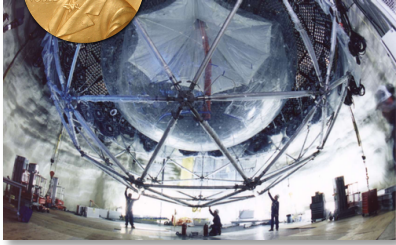
September 2015



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Science

# NERSC Science Highlights September 2015

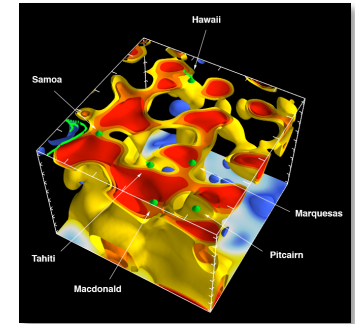


## Particle Physics

Nobel prize honors the discovery that neutrinos have mass and oscillate between different types. (Yuen-Dat Chan , LBNL)

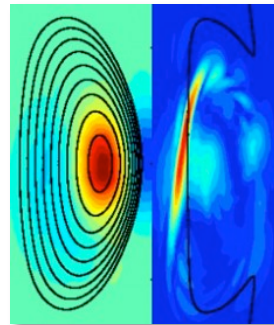
## Geophysics

3D scan of Earth's interior connects plumes of hot rock rising through the mantle with surface hotspots that generate volcanic islands (B. Romanowicz, UC Berkeley)



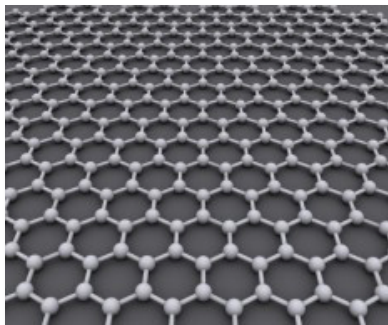
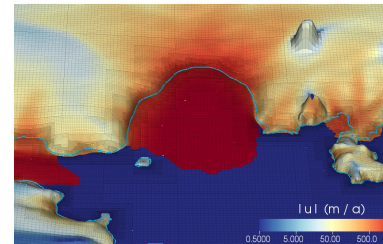
## Fusion Energy

3D simulations yield new insights into why plasma in a Tokamak fusion reactor fails to reach required temperatures (R. Davidson/E. Belova , PPPL)



## Climate

Study estimates how much ice the W. Antarctic Ice Sheet could lose over the next two centuries and how that could impact sea-level rise (D. Martin , LBNL)

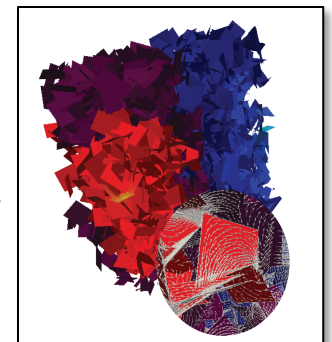


## Materials Science

Simulations show that hitting graphene with circularly polarized laser pulses can cause it to change state from a semi-metal to an insulator. (T. Devereaux , SLAC)

## Renewable Energy

Ensemble simulations of flow through geothermal fracture networks improve reliability & economics of renewable geothermal energy. (Melior Innovations Inc.)



# Nobel Prize in Physics 2015

Arthur B. McDonald, Queen's University (SNO)  
Takaaki Kajita, Tokyo University (Super Kamiokande)

## Scientific Achievement

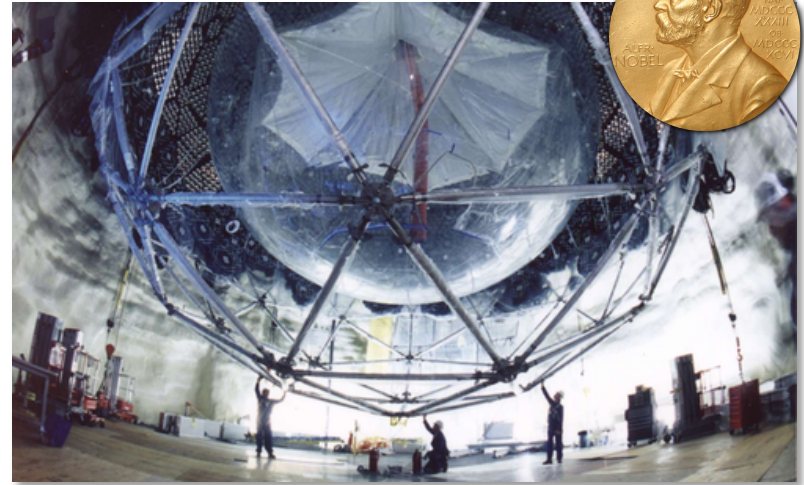
The discovery that neutrinos have mass and oscillate between different types.

## Significance and Impact

The discrepancy between predicted and observed solar neutrinos was a mystery for decades. This discovery overturned the Standard Model interpretation of neutrinos as massless particles and resolved the “solar neutrino problem.”

## Research Details

- The Sudbury Neutrino Observatory (SNO) detected all three types (flavors) of neutrinos and showed that when all three were considered, the total flux was in line with predictions.
- This, together with results from the Super Kamiokande experiment, was proof that neutrinos were oscillating between flavors and therefore had mass.



A SNO construction photo shows the spherical vessel that would later be filled with water.

NERSC helped the SNO team use PDSF for critical analysis contributing to their seminal PRL paper. HPSS serves as a repository for the entire 26 TB data set.

Q. R. Ahmad et al. (SNO Collaboration). Phys. Rev. Lett. 87, 071301 (2001)



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NERSC PI: Yuen-Dat Chan (LBNL)





# CT Scan of Earth Links Mantle Plumes with Volcanic Hotspots

## Scientific Achievement

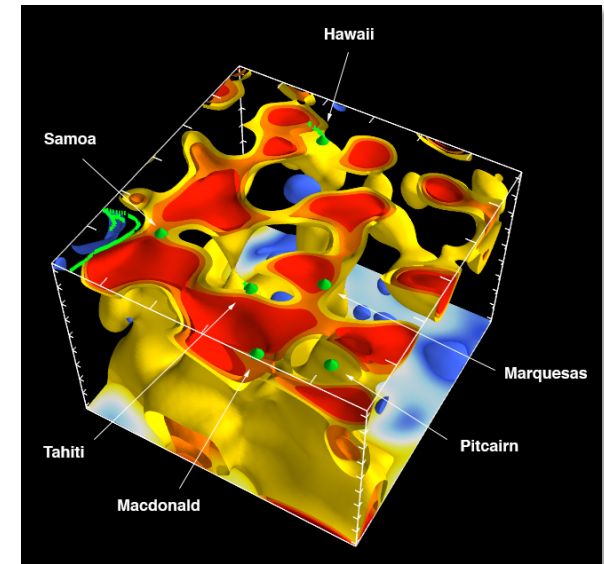
UC Berkeley seismologists produced for the first time a 3D scan of Earth's interior that conclusively connects plumes of hot rock rising through the mantle with surface hotspots that generate volcanic island chains.

## Significance and Impact

Evidence for the plume and hotspot theory had previously been circumstantial; the theory has now been confirmed

## Research Details

- To create a high-res CT scan of Earth, the researchers ran numerical simulations of how seismic waves travel through the mantle and compared them to the ground motion actually measured by detectors around the globe. The simulations, run on NERSC's Edison system, computed all components of the seismic waves.
- The model was tweaked repeatedly to fit recorded data using a method similar to statistical regression. The final computation required 3 million CPU hours on NERSC's supercomputers; parallel computing shrank this to a couple of weeks.



*A 3D rendering of shear wave speed anomalies beneath the Central Pacific between the core-mantle boundary (2891 km depth) and 400 km depth. Green cones and labels highlight locations of key hotspot volcanoes in this region.*

S. French, B. Romanowicz  
Nature 525, 95-99, Sep. 3, 2015





# Electron Heat Loss in Fusion Plasma

## Scientific Achievement

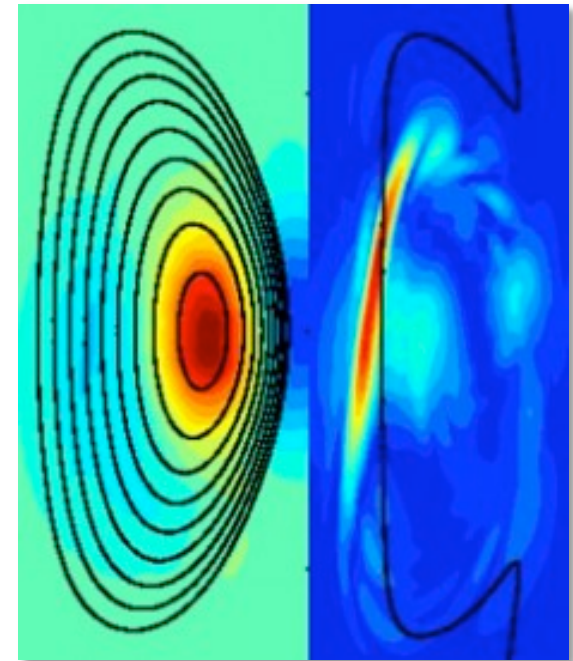
3D simulations at NERSC yield new insights into why hot plasma in a Tokamak fusion reactor sometimes fail to reach required temperatures.

## Significance and Impact

The findings could lead to improved temperature control in fusion devices and enhance understanding of electron energy transport in fusion experiments.

## Research Details

- One of the largest remaining mysteries in plasma physics is how electron heat is transported out of the plasma
- 3D simulations run on NERSC's Hopper system using data from the National Spherical Tokamak Experiment – Princeton Plasma Physics Laboratory's major fusion experiment – showed that two kinds of waves in fusion plasmas appear to form a chain that transfers neutral-beam energy from the plasma core to the edge, where the heat dissipates



*Contour plots of magnetic-field perturbation show resonant coupling between compressional Alfvén eigenmodes (CAE) and kinetic Alfvén waves (KAWs), which leads to heat dissipation in a reactor.*

Belova, Gorelenkov, Fredrickson, Tritz, Crocker  
Phys. Rev. Lett. 115, June 29, 2015



# BISICLES Ice Sheet Model and Climate Change

## Scientific Achievement

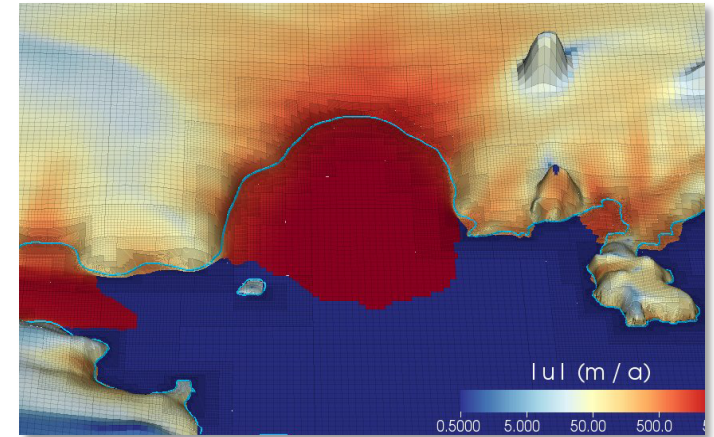
A new high-resolution, large-scale computer model - Berkeley-ISICLES (BISICLES) - estimated how much ice the W. Antarctic Ice Sheet could lose over the next two centuries and how that could impact sea-level rise

## Significance and Impact

The acceleration of West Antarctic ice streams in response to ocean warming could result in a major contribution to sea-level rise, but previous (lower resolution) models were unable to quantify this

## Research Details

- Running simulations at NERSC, the research team subjected the BISICLES model to a range of ocean and atmospheric change: no change at all, future changes projected by ocean and atmosphere models, and extreme changes intended to study the upper reaches of future sea-level rise
- The results of global climate models were fed into regional models of the Antarctic atmosphere and ocean, whose results were in turn used to force the ice-sheet model in this study



*Computer simulations run at NERSC show estimates of ice retreat in the Amundsen Sea Embayment by 2154. West Antarctica is one of the fastest warming regions on Earth, and its ice sheet has seen dramatic thinning in recent years. The ice sheet is losing significant amounts of ice to the ocean, with the losses not being offset by snowfall.*

S.L. Cornford, D. Martin et al  
The Cryosphere, 9, 1579-1600, 2015



# Polarized Laser Pulses Could Change Nature of Graphene

## Scientific Achievement

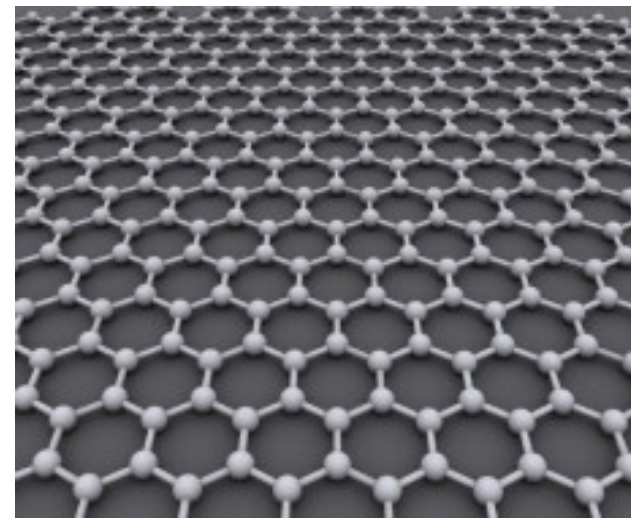
Simulations run at NERSC show that hitting graphene with realistic low-frequency circularly polarized laser pulses can cause it to change state from a semi-metal to an insulator.

## Significance and Impact

Graphene could be used to replace traditional semiconductors to encode and store information, with possible applications in low-energy electronics, quantum computing, light detectors ...

## Research Details

- Theorists used NERSC's Hopper supercomputer to perform large-scale simulations of an experiment in which graphene is hit with circularly polarized pulses a few millionths of a billionth of a second long.
- The results showed that the “handedness” of the laser pulses led to interesting and unexpected properties: not only does it produce a band gap, but it also induces a quantum state that can be switched either “on” or “off.”



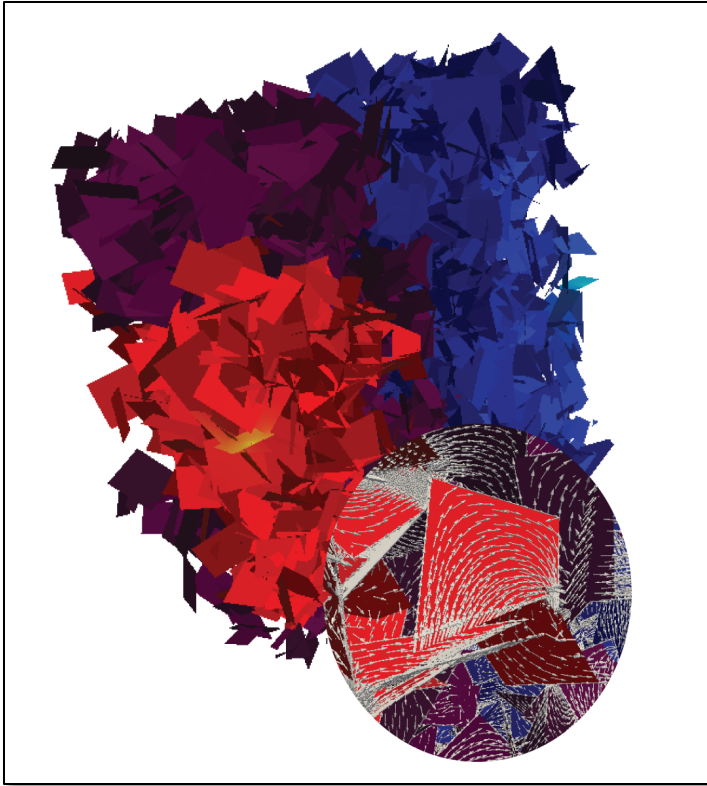
*This illustration depicts the structure of graphene, which consists of a single layer of carbon atoms arranged in a honeycomb pattern. A new simulation suggests that spiraling pulses of polarized laser light could change graphene's nature, turning it from a metal to an insulator.*

Sentef, Claassen, Kemper et al.,  
2015, Nature Communications 6, 70475





# High Accuracy Modeling of Geothermal Wells



*NERSC's Edison simulates fluid flow through a network of 2900 subsurface fractures. "Using FeNICS on HPC Systems" Chris Richardson and David Bernstein, FeNICS2015 Conference*

Work was performed at Melior Innovations Inc.

## Scientific Achievement

Ensemble simulations of flow through geothermal fracture networks improve reliability & economics of renewable geothermal energy.

## Significance and Impact

- Geothermal comprises 18% of California's renewable electricity generation.
- Drilling costs \$5M per well, flow simulation improves economics of geothermal over lifetime of field.

## Research Details

- Subsurface networks containing thousands of fractures present complex dynamic flow and diffusion problems.
- Using NERSC, Melior Innovations Inc. scaled up solver code from cluster-scale to HPC scale
- 92% parallel efficiency on 10k cores; Now fracture networks from [Earthquake Data Center](#) can be incorporated to improve simulation fidelity.



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