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Title: Los Alamos National Laboratory Statistical Sciences Group

Author(s): Vander Wiel, Scott A.
Wendelberger, Joanne R.

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Los Alamos National Laboratory Statistical Sciences Group



Joanne Wendelberger, Group Leader
Scott Vander Wiel, Deputy Group Leader

stat.lanl.gov

Who We Are

Group Composition

- 18 Ph.D. Statisticians
- 2 M.S./B.S. Statisticians
- 1 M.S. Math
- 1 Ph.D. Computer Scientist
- 1 Ph.D. Sociologist
- Administrative Support

Special Programs

- 2 Post Docs (in past year)
- 7 grad & undergrad students
- 2 R&D Contractors
- ~15 Guests / yr

What We Do

- Bring statistical reasoning and rigor to multi-disciplinary scientific investigations through development, application, and communication of cutting-edge statistical sciences research.
- Develop techniques for collecting, analyzing, combining, and making inferences from diverse qualitative and quantitative information sets such as experiments, observational studies, computer simulations, and expert judgment.

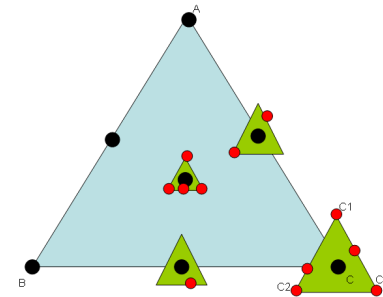
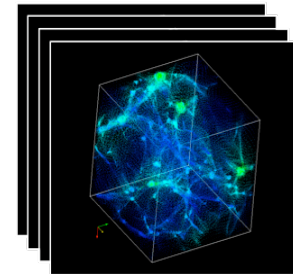
Our History

Founded as the Statistics Group in 1967, the group has partnered with scientists, engineers, and policy makers within and outside the Laboratory to solve problems of national importance for 45 years.

We have outlasted many reorganizations, with many monikers: T-5, C-5, T-5, Q-12, S-1, A-1, TSA-1, D-1, CCS-6.

Technical Capabilities

- Data Analysis, Modeling, Inference
- Computer Model Evaluation/Uncertainty Quantification
- Design and Analysis of Experiments
- Classification and Anomaly Detection
- Streaming Data
- Statistical Analysis of Networks and Graphs
- Biological Analysis and Biosurveillance
- Computational Statistics
- Monitoring and Process Control
- Monte Carlo Methods
- Reliability, Engineered Systems
- Sampling Theory and Applications
- Resource Allocation
- Socio-Technological Modeling and Analysis



Stockpile Stewardship: Reliability Modeling and Assessment

- Provide advance warning of manufacturing and aging defects that could affect the nuclear weapons stockpile
- Requires system models that capture parts, functions, dynamics, and interactions
- Integrate multiple data sources, including historical data, surveillance testing, accelerated life testing, computer model output, and materials characterization

UNITED STATES NUCLEAR WEAPONS STOCKPILE					
					
BOMB	DESCRIPTION	CARRIER	LABORATORIES	MISSION	MILITARY
B61 - 3/4/10	Tactical Bomb	F-15, F-16	Los Alamos/Sandia	Air to Surface	Air Force
B61 - 7/11	Strategic Bomb	B-52 & B-2	Los Alamos/Sandia	Air to Surface	Air Force
					
WARHEAD	DESCRIPTION	CARRIER	LABORATORIES	MISSION	MILITARY
W62	ICBM Warhead	Minuteman III ICBM	LLNL/Sandia	Surface to Surface	Air Force
W78	ICBM Warhead	Minuteman III ICBM	Los Alamos/Sandia	Surface to Surface	Air Force
					
WARHEAD	DESCRIPTION	CARRIER	LABORATORIES	MISSION	MILITARY
W76	SLBM Warhead	C4 & D5 Missiles, Trident Submarines	Los Alamos/Sandia	Underwater to Surface	Navy
W88	SLBM Warhead	D5 Missiles, Trident Submarines	Los Alamos/Sandia	Underwater to Surface	Navy
					
WARHEAD	DESCRIPTION	CARRIER	LABORATORIES	MISSION	MILITARY
W87	ICBM Warhead	Peacekeeper ICBM	LLNL/Sandia	Surface to Surface	Air Force
					
BOMB	DESCRIPTION	CARRIER	LABORATORIES	MISSION	MILITARY
B83 - 0/1	Strategic Bomb	B-52 & B-2	LLNL/Sandia	Air to Surface	Air Force
					
BOMB	DESCRIPTION	CARRIER	LABORATORIES	MISSION	MILITARY
W80 - 0	TLAM - N	Attack Submarine	Los Alamos/Sandia	Underwater to Surface	Navy
W80 - 1	ALCM/ACM	B-52	Los Alamos/Sandia	Air to Surface	Air Force

Radio-Astronomical Bursts

Use radio interferometers to detect objects that emit fast ($<1\text{s}$) bursts of energy:

Pulsars (regular + giant pulses),
black hole evaporation,
coalescing neutron stars, rotating
radio transients, flare stars,
electromagnetic waves, ???

Statistical Challenge: High data rates
(eg., $\sim 1\text{GB/min}$), with

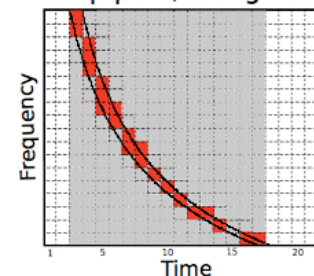
- white noise (vast majority)
- interference (terrestrial and satellite)
- astronomical bursts (very rare)



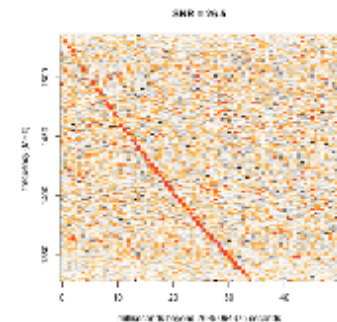
Very Large Array,
Socorro, NM



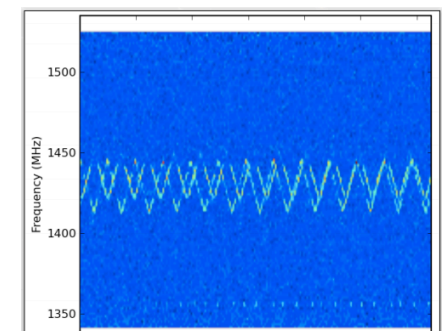
Theoretical burst
Chirp path/background



Strong actual burst



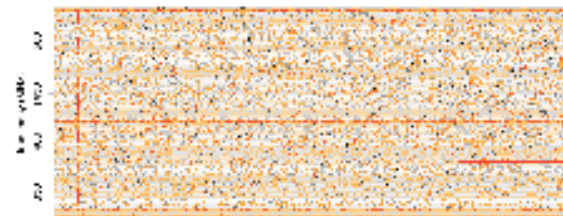
Satellite interference





Simieon, et. al., 2011



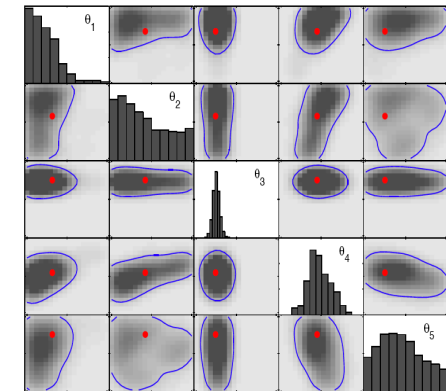
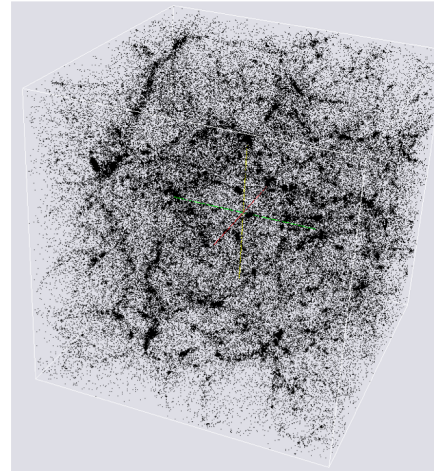
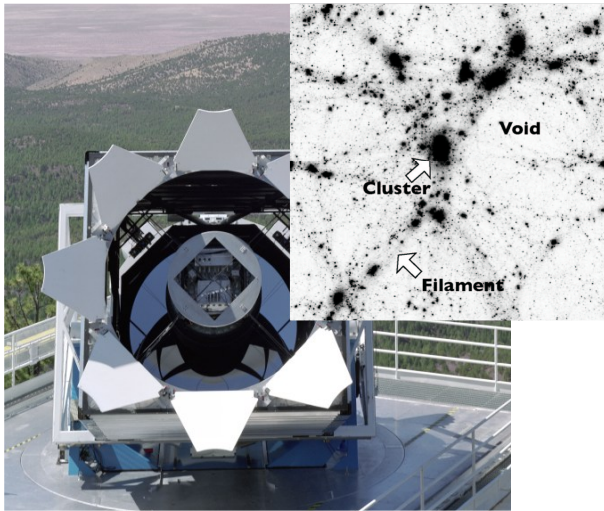
transient interference



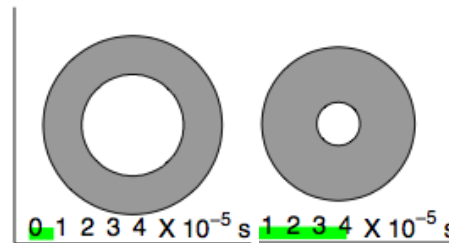
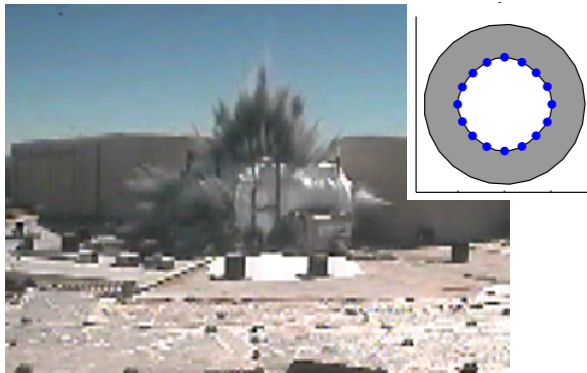
Fusing simulations and observations for parameter estimation, prediction and uncertainty quantification

Observation/experiment  simulations  Calibration: find simulation parameters consistent with observations

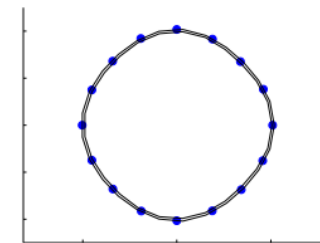
large scale structure of universe



Hydrodynamic behavior



prediction uncertainties

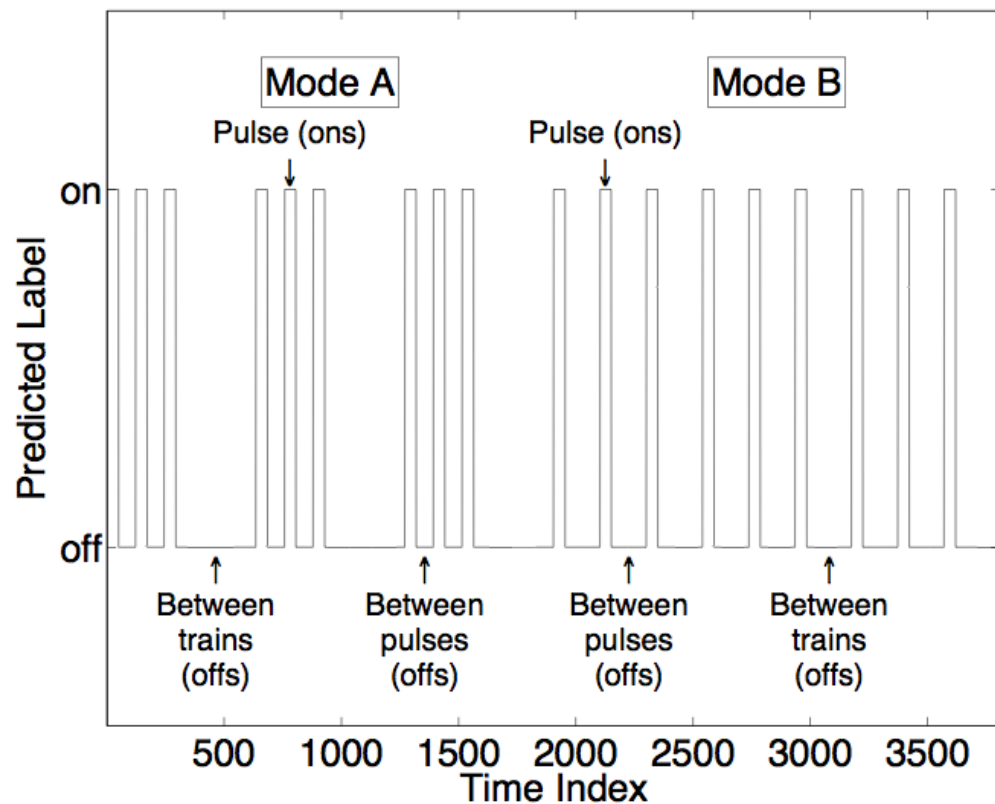
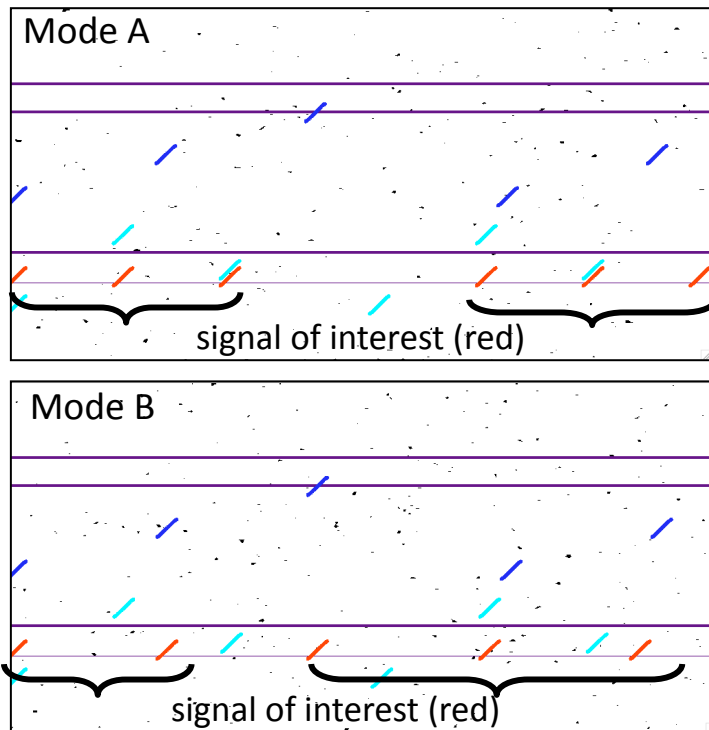


Statistical methods originally developed to support NW certification have been adapted to address key questions in cosmology. A sequence of simulations is combined with physical observations to constrain unknown model parameters and give prediction uncertainties.

Facility Monitoring

Develop algorithms that will automatically discover evidence of nuclear proliferation activities in electromagnetic signals

Methods: Time series analysis, kernel density est., hidden Markov models

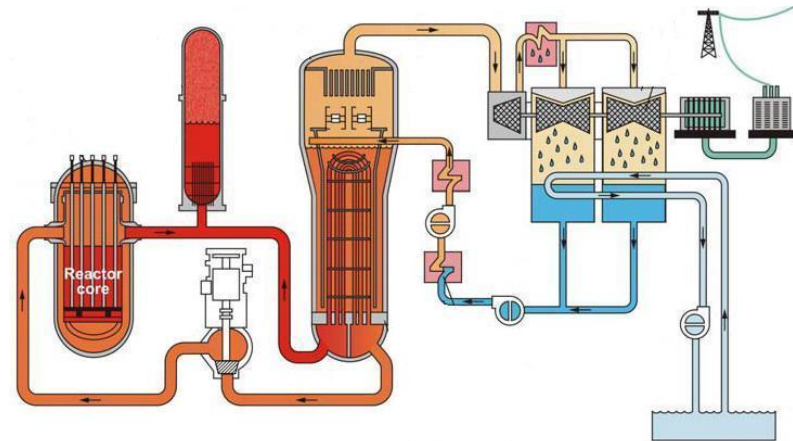


Interested parties: IAEA, NNSA, DHS

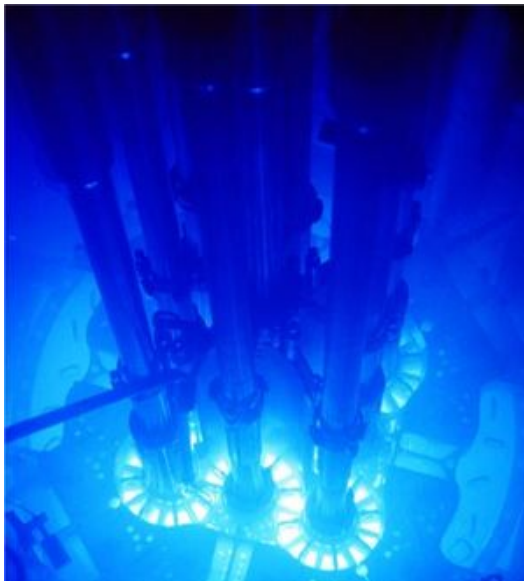
DAEMON: Dynamic Analysis of ElectroMagnetic Observations for Nonproliferation

Nuclear Energy: Reactor Sustainability

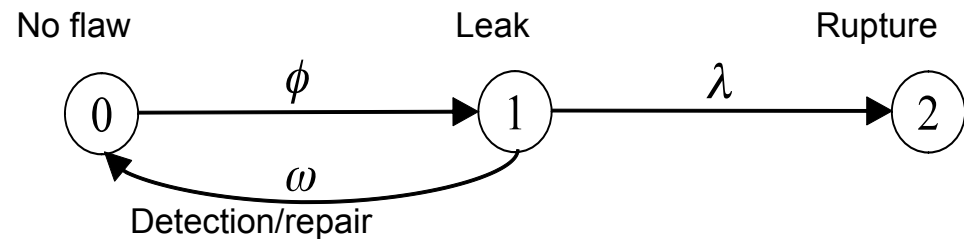
- Computer models, calibration
- Flowgraph models for Markov and semi-Markov processes
- Bayesian methods
- Stochastic differential equations



Fluid flows in a reactor



Reactor core



Flowgraph Reliability Model

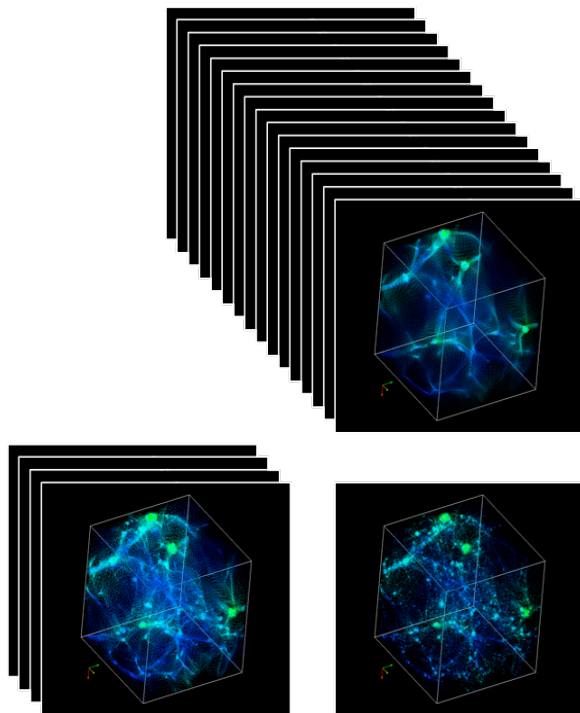
Cosmology: Large-Scale Structure of the Universe

Simulate many universes at different cosmological settings

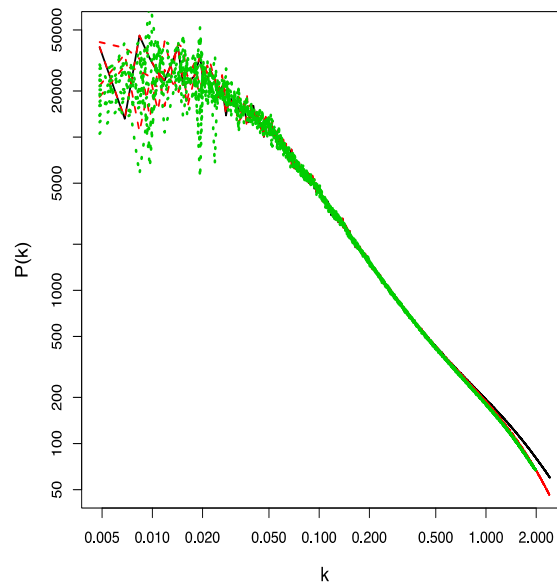
Analyze data from computer experiments

Gaussian processes used to build an emulator

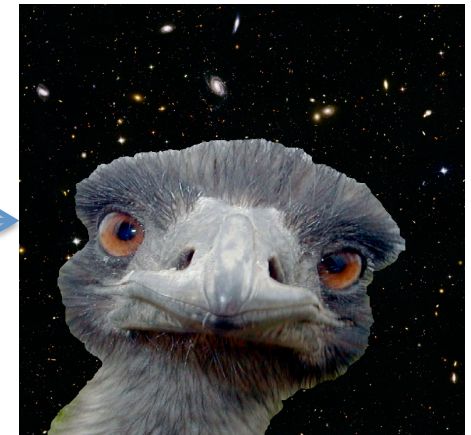
Predict the smooth power spectrum of untested inputs to simulation



Multiple Runs at Multiple
Resolutions



power spectrum
of matter



CosmicEmu

Nuclear Nonproliferation

Member states (Eg: Japan) sign nonproliferation treaty and declare all nuclear-related activities.

First line of defense: Declared facilities

1991: International Atomic Energy Agency (IAEA) discovered undeclared highly-enriched Uranium facility in Iraq. This led to “integrated/strengthened” safeguards and **huge amounts of data, including operator data from nuclear facilities.**



Second line of defense: Border crossings

Network interdiction models, sensor optimization, isotope identification, drifting background, background suppression, spoof scenarios with passive detector → detect shielding using, for example, muon radiography.



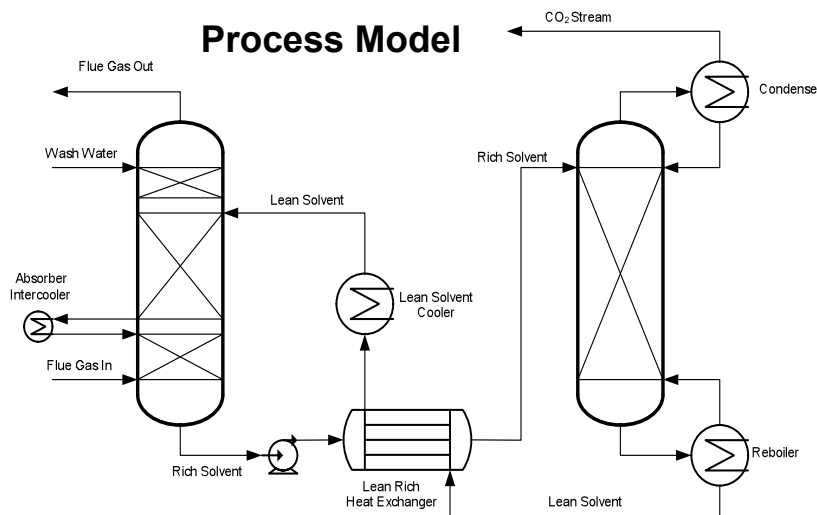
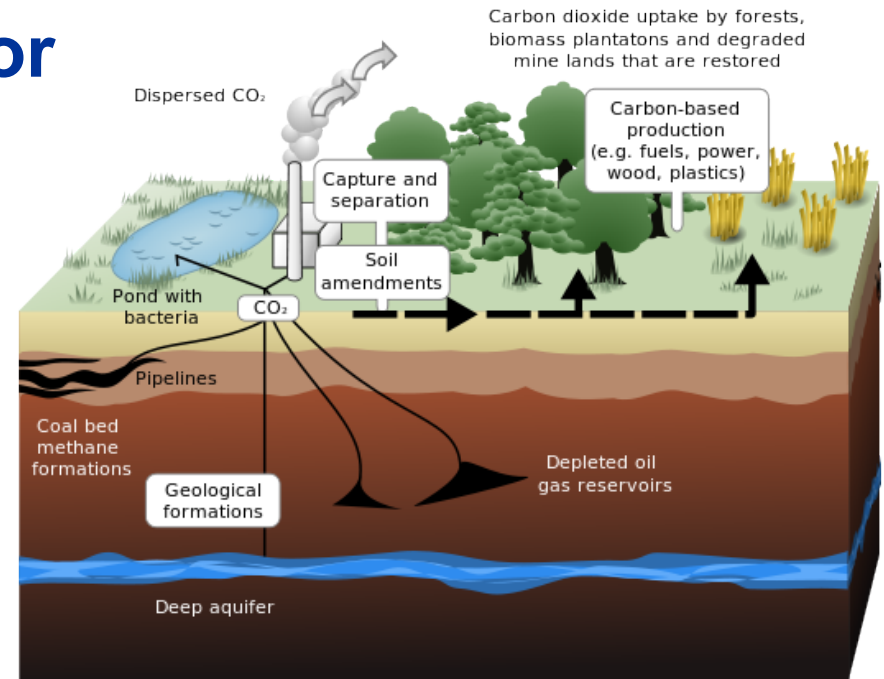
Statistical Issues:

- Challenging “natural” background
- Modeling signals of interest. Model uncertainty of growing importance
- Many monitoring options because there are multiple signals of interest
- Heterogeneous data streams on different time scales

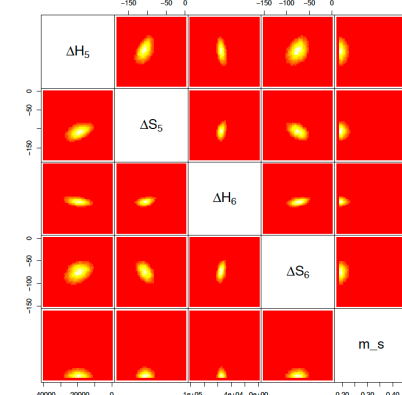
Goal: Detect undeclared activity if it occurs

Uncertainty Quantification for Carbon Capture Simulation

Understand and quantify uncertainty in carbon capture simulation models to accelerate development of cleaner, more efficient energy production.



Parameter Uncertainty



Staffing and Recruiting

- Search for entry or mid-career Ph.D. Statistician starting now (see stat.lanl.gov)
- We conduct a national search
 - 1 ½ day interview
 - technical presentation on dissertation research
 - 2011 search: ~150 applicants, 5 interviewed, 1 hired (from ISU!)
- In math, hires often start as post-docs with possible transition to full time staff (see cnls.lanl.gov)

The Statistics Group at Los Alamos

- Colleagues are PhD statisticians, computer scientists, mathematicians
- Project work is hugely interdisciplinary:
physics, material science, chemistry, computer science, signal processing, astronomy, geology, hydrology, seismology, high-energy physics, magnetism, radio-chemistry, high explosives, cyber security, orbital dynamics, ...
- Funding sources
U.S Departments of Energy, Defense, Homeland Security, Education, DOE Office of Science, Laboratory Directed R&D, University of California, National Nuclear Security Agency, Intelligence Community (three letter agencies), Proctor & Gamble, Chevron, ...
- Projects
 - Often 2 from stats, math, and CS combined with other scientists
 - Vary from six months to 5 years
 - Typically work on 3-5 at once

Work-life in the Statistics Group

Professional development

- 1-10+ publications per year
- Organized first DOE Conference on Data Analysis (2012)
- AEs and reviewers for journals
- Officers in ASA and ASQ
- Program committees
- Creating ASA Section on Uncertainty Quantification
- National Academies of Science study panels
- Six fellows of the American Statistical Association

We have fun

Talking to Ourselves Seminars, Suave Football Bowl, Methods for Ranking College Football, lunchtime dictionary trivia, Marti Gras Cake, Christmas white elephant party, weekly coffee time, lots of laughter, experimental design for lawn watering, every other Friday off!

Los Alamos

7200' in Northern New Mexico
Great ski areas 15 min — 2 hours
Parades, churches, music, mountain runs
Hike, bike, run, swim, hunt, camp, fish
45 minutes to Santa Fe

What Skills do we Value?

- Technical depth, as shown in dissertation work, publications, faculty recommendations
- Depth of interest in applications, as shown in dissertation work, internships, undergraduate degree, assistantships, work experience
- Well-roundedness, ability to collaborate
- Ability to obtain a security clearance (which typically requires U.S. citizenship)

Center for Nonlinear Studies (applied math)

Part of the Theoretical Division

- Organizes research related to nonlinear & complex systems
- Statistical physics, applied math, numerical simulation, nonlinear science
- Consists of Director, Executive Committee and 30+ postdocs
- Postdocs sponsored by projects with LANL staff

Currently seeking postdocs in ...

- multiscale phenomena in materials, discrete simulation of nonlinear systems,
- probabilistic and combinatorial analysis of biological systems,
- applications of nonlinear and stochastic dynamics,
- self-organization and pattern formation,
- landscapes and dynamics of proteins

with applications in ...

condensed matter and plasma physics, fluid dynamics, chemistry, materials science, theoretical biology, neural networks, parallel computation



Center for Nonlinear Studies (applied math)

Sample of recent workshop topics

- Computational Methods for High-Dimensional and Complex Data Sets
- Conference on Global and Regional Climate Change
- Optimization and Control of Smart Grids for Electrical Power
- Summer School for Cellular Information Processing
- Advanced Simulation Techniques for Total Scattering Data
- Statistical Image Analysis
- The Oceans and Turbulence



National Laboratories (U.S. Department of Energy)

