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Sequential Tempered Markov Chain Monte Carlo:
Accelerating Bayesian Inference, Model Selection, and Uncertainty Quantification

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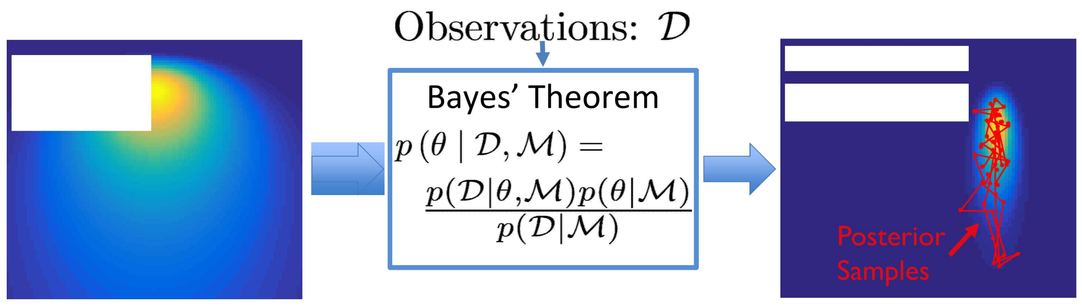
Problem

The Bayesian Perspective:

We update uncertainty as information or observations (D) are added (Bayes' Theorem)



Applications
- Calibrate model parameters p(θ|D)
- Compare model structures p(M|D)
- Predict failures from data p(F|D)

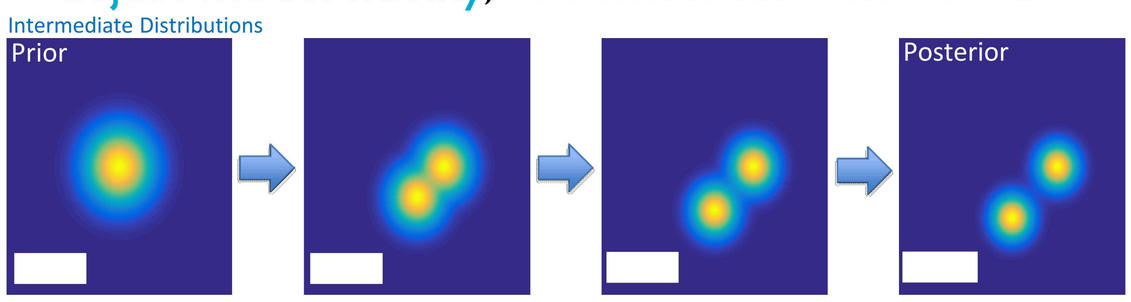
Challenges of Bayesian Methods:

- Markov Chain Monte Carlo (MCMC) is often used to sample the posterior in these applications
- We desire MCMC methods that quickly explore the posterior, require little tuning, can be parallelized, and leverage multifidelity models

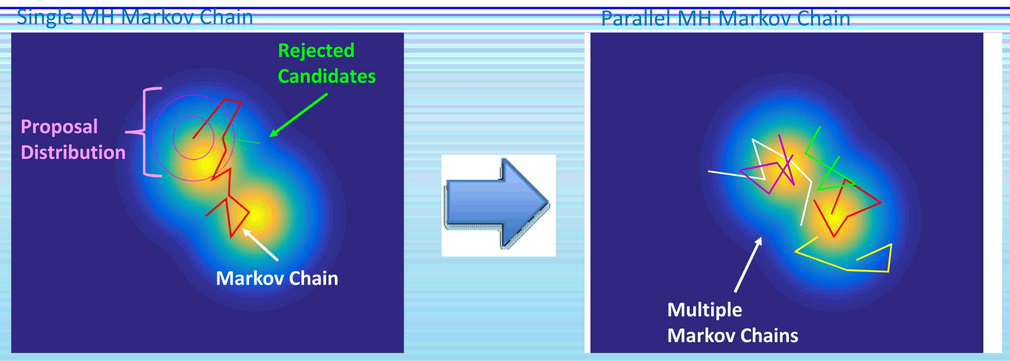
Approach

Sequential Tempered MCMC[‡] (ST-MCMC) :

- Update prior to posterior through intermediate distributions to aid exploration
- These distributions can gradually introduce data, adjust model fidelity, or relax failure thresholds



- Parallel MCMC chains quickly explore and sample the intermediate distributions



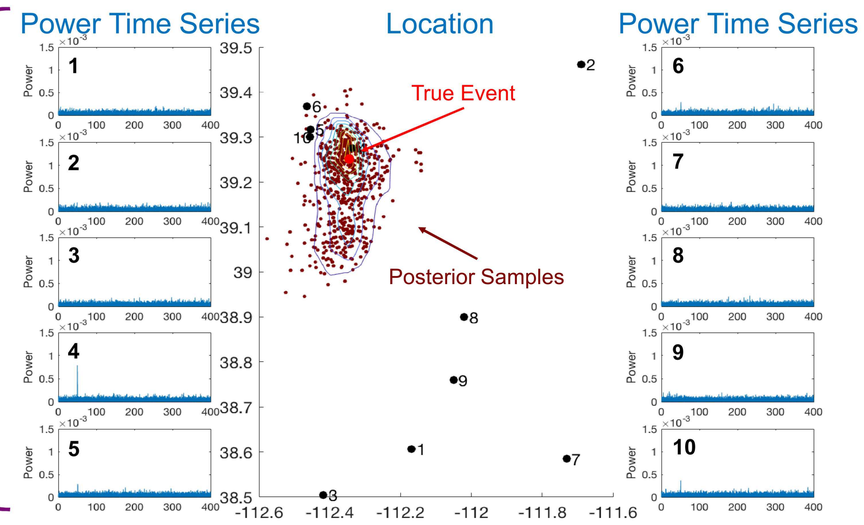
- ST-MCMC adapts online based on statistics from the intermediate samples with little user tuning

Results

Seismic Monitoring via Bayesian Inference:

- Identify the location and magnitude of weak seismic events from observed waveforms with uncertainty
- ST-MCMC adapts to integrate sensors and improve uncertainty models

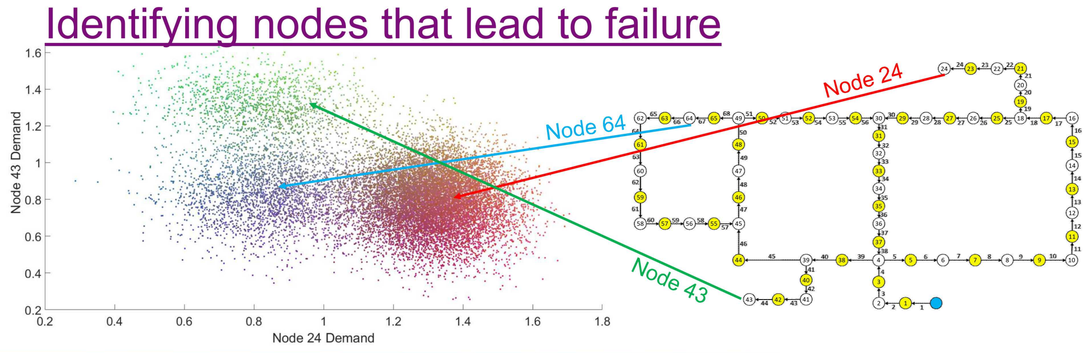
Example Identification of weak event



Water Distribution System Reliability:

- Estimate the failure probability for a system with unknown parameters using water pressure data
- ST-MCMC simultaneously solves the model calibration and reliability problem over 10x faster than state-of-the-art

Identifying nodes that lead to failure



Significance

ST-MCMC Impact:

- ST-MCMC provides an efficient, flexible, and robust method for Bayesian uncertainty quantification
- ST-MCMC enables waveform-based seismic monitoring, which has been held back by computational cost
- ST-MCMC addresses poster44ior system reliability, which has not been done previously

Future Work:

- Information theory for intermediate distributions
- Improve adaptation methods via machine learning

Funding

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[‡]Catanach, T A., and J. L. Beck "Bayesian updating and uncertainty quantification using sequential tempered MCMC with the rank-one modified metropolis algorithm" arxiv.org1804.08738 (2018)