2020 MATH + X Symposium on Inverse Problems and Deep Learning, Mitigating Natural Hazards

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2020 MATH + X Symposium on Inverse Problems and Deep Learning, Mitigating Natural Hazards

Las Catalinas, Guanacaste, Costa Rica · January 29–31

Agenda

Tuesday, January 28 Ponciana

7:00pm	*reception*	

Wednesday, January 29 Santarena, The Conservatory

6:30am	breakfast, Ponciana	
8:15am	opening remarks	de Hoop, Jenkins, Protti
		Chair: de Hoop
8:30am	**Keynote:** Modeling Sea Ice in a Changing Climate	Golden
9:30am	Large Neural Networks Beyond the Kernel Regime	Bruna
10:15am	*coffee/juice break*	
10:45am	Anticipation of Large Subduction Earthquakes in Costa Rica	Protti
11:15am	Volcanic Activity in Costa Rica	Pacheco
11:30am	*spotlights: Seydoux, Begland, Rodriguez*	
11:45am	Recovery of Material Parameters in Transversely Isotropic Media	Vasy
12:30pm	*lunch, Limonada*	

3:30pm	*coffee/juice break*	
		Chair: Uhlmann
4:00pm	Seismology Beyond Earthquakes: Using Continuous Seismic Data for Imaging and Monitoring	Shapiro
4:45pm	**Keynote:** Tackling Challenges in Flood Forecasting with Machine Learning	Nevo
5:45pm	Earth System Modeling 2.0: Toward Data-Informed Climate Models With Quantified Uncertainties	Schneider
6:30pm	*adjourn*	
7:30pm	*dinner, Plaza Danta*	

Thursday, January 30 Santarena, The Conservatory

6:30am	*breakfast, Ponciana*	
		Chair: van der Hilst
8:30am	**Keynote:** Watching and Listening to Fracture	Weitz
9:30am	Fast Bayesian Discovery of Pairwise Interactions in High Dimensions	Broderick
10:15am	*coffee/juice break*	
10:45am	New Deep Neural Networks Solving Nonlinear Inverse Problems	Lassas
11:30am	*spotlights: Molitor, Balestriero, Railo*	
11:45am	Tsunamis Warning and Submerged Volcanic Activity Monitoring: New Detection Techniques	Chierici
12:30pm	*lunch, Limonada*	
3:30pm	*coffee/juice break*	
		Chair: Johnson
4:00pm	**Keynote:** Mathematics of Deep Learning	Vidal
5:00pm	Inverse Spectral and Resonance Problems for Elastic Surface Waves	Iantchenko
5:45pm	*coffee/juice break*	

6:15pm	Supershear Earthquakes and Tsunamis	Bhat
7:00pm	Deep Learning for Signal Processing	Fernandez-Granda
7:45pm	*adjourn*	
8:00pm	*symposium dinner, Limonada 2nd floor*	

Friday, January 31 Santarena, The Conservatory

6:30am	*breakfast, Ponciana*	
		Chair: Ramirez
8:30am	**Keynote:** Extreme Event Quantification in Dynamical Systems with Random Components	Vanden-Eijnden
9:30am	A New Approach Using AI in Volcano Seismology and Forecasting Eruptions	Ibanez
10:15am	*coffee/juice break*	
10:45am	Finite Element Methods for Unique Continuation	Oksanen
11:30am	*spotlights: van der Laat, Ratti, Gutiérrez*	
11:45am	Machine Learning Identifies Universal Fault Friction Characteristics	Johnson
12:30pm	*lunch, Limonada*	
3:30pm	*coffee/juice break*	
		Chair: de Hoop
4:00pm	Deep Generative Approaches to Help Mitigate Climate Change	Schmidt
4:45pm	The Geometry of Anisotropy	Ilmavirta
5:30pm	Cloud Storage Applications of Algebraic Surfaces via Coding Theory	Várilly-Alvarado
6:15pm	*adjourn*	
7:00pm	*dinner, Limonada*	

Abstracts — Wednesday, January 29

8:30am **Kenneth Golden** *University of Utah*

Modeling Sea Ice in a Changing Climate

Polar sea ice is a key component of Earths climate system. As a material it exhibits complex composite structure on length scales ranging from tenths of millimeters to tens of kilometers. A principal challenge in modeling sea ice and its role in climate is linking small scale structure to effective or homogenized behavior on larger scales, and estimating parameters controlling small scale processes from large scale observations. Similar issues are central to the development of advanced composite materials. I will give an overview of how we are using the mathematics of composite media and statistical physics to link behavior on various scales in the sea ice system. These mathematical advances, motivated by sea ice, tell us more generally about the effective properties of various multiscale composite systems, and how to address the inverse problem of reconstructing composite microstructure from effective property measurements. In particular, we consider fundamental questions in sea ice homogenization, including fluid flow through the porous brine microstructure, effective properties of polycrystalline materials, the interaction between ocean surface waves and the sea ice pack, advection enhanced diffusion, and the evolution of melt ponds on Arctic sea ice. This work is helping to advance how sea ice is represented in climate models, and to improve projections of the fate of Earths sea ice packs and the ecosystems they support.

9:30am **Joan Bruna** *New York University*

Large Neural Networks beyond the Kernel Regime

Virtually all modern deep learning systems are trained with some form of local descent algorithm over a high-dimensional parameter space. Despite its apparent simplicity, the mathematical picture of the resulting setup contains several mysteries that combine statistics, approximation theory and optimization, all intertwined in a curse of dimensionality.

In order to make progress, authors have focused in the so-called overparametrised regime, which studies asymptotic properties of the algorithm as the number of neurons grows. In particular, neural networks with a large number of parameters admit a mean-field description, which has recently served as a theoretical explanation for its favorable training properties. In this regime, gradient descent obeys a deterministic partial differential equation (PDE) that converges to a globally optimal solution for networks with a single hidden layer under appropriate assumptions.

In this talk, we will review recent progress on this problem, and argue that such framework might provide crucial robustness against the curse of dimensionality. First, we will describe a non-local mass transport dynamics that leads to a modified PDE with the same minimizer, that can be implemented as a stochastic neuronal birth-death process, and such that it provably accelerates the rate of convergence in the mean-field limit. Next, such dynamics fit naturally within the framework of total-variation regularization, which following [Bach17] have fundamental advantages in the high-dimensional regime. We will discuss a unified framework that controls both optimization, approximation and generalisation errors using large deviation principles, and discuss current open problems in this research direction.

Joint work with Z. Chen, G. Rotskoff, and E. Vanden-Eijnden.

10:45am **Marino Protti** *Universidad Nacional Costa Rica*

Anticipation of Large Subduction Earthquakes in Costa Rica

Fast plate convergence, land right over the seismogenic zone, relatively small coupled areas and therefore short recurrence intervals for large earthquakes make Nicoya and Osa-Burica peninsulas off Western Costa Rica excellent sites for the operation of earthquake cycle observatories. In these localities, seismic and geodetic instrumentation have the potential to document crustal deformation over an entire earthquake cycle and hopefully for several earthquake cycles.

At the Nicoya segment of the MAT, and since the 1990s, a dense geodynamic control network of seismic and geodetic instruments was installed over the seismogenic zone. Campaign and continuous GPS data that expanded for almost two decades were crucial in delineating heterogeneities along the plate interface and anticipating the area where the next earthquake would potentially occur and the magnitude it could reach. This network successfully captured the preseismic, coseismic and postseismic deformation associated with the Nicoya September 5th, 2012, (Mw=7.6) earthquake.

Under the Osa and Burica peninsulas in South Eastern Costa Rica, where an aseismic ridge subducts bellow the Panama microplate, large earthquakes have occurred in 1856, 1904, 1941 and 1983. Osa and Burica peninsulas lie only 10 to 25 km from the trench; the angle of the plate interface is lower than under Nicoya and therefore possesses the potential to produce, through seismic and geodetic monitoring, a very detailed map of heterogeneities along the seismogenic zone.

Mapping and tracking the loading and failure evolution of these medium-size patches can lead to more precise assessments of size, location and timing of future earthquakes. With that purpose, OVSICORI-UNA is completing a dense geodynamic monitoring network on and around the Osa and Burica peninsulas to capture and map the rupture area, also in the near field, of a Mw=7.2-7.4 earthquake that will likely occur in the next 5 years.

11:15am **Javier Pacheco** *Universidad Nacional Costa Rica*

Volcanic Activity in Costa Rica

Costa Rica lies along the so-called “Ring of Fire”, a narrow band around the Pacific Ocean with active seismicity and volcanism. Tectonic collision between the Coco and Caribbean plates is the source of seismicity and active volcanic centers in Costa Rica. Nine of these volcanic complexes produced geologic features associated with Holocene eruptions, and are considered active volcanoes, with potential activity, though only three of them currently. Both OVSICORI and the RSN monitor the activity of these nine volcanic complexes with varying types of instrumentation. The active volcanoes are monitored with seismic networks which allow, after interpretation, to assess the level of activity and, with the Civil Protection Authorities, to take precautions against potential hazards. Seismic traces are reviewed daily by seismologists extracting information on the type, number and characteristics of seismic events. This process is time consuming and too slow for implementing a quick response to safeguard the exposed population. Here, we describe the advances in automatization of these processes, with algorithms from pattern recognition and artificial intelligence, in order to improve on procedures to handle volcanic hazards.

11:30am **Leonard Seydoux** *Université Grenoble-Alpes*

Spotlight: Unsupervised Clustering of Events and Noises in Continuous Seismograms

11:35am **Katherine Begland** *Rice University*

Spotlight: Stable GANs for Unsupervised Synthesis and Internal Representation of Geodynamics

11:40am **Angel Bueno Rodriguez** *Universidad de Granada*

Spotlight: Applying Uncertainty in Seismic Volcano Monitoring to Better Identify Dynamics

11:45am **Andras Vasy** *Stanford University*

Recovery of Material Parameters in Transversely Isotropic Media

In this talk I will discuss recent developments regarding the recovery of material parameters in anisotropic elasticity, in the particular case of transversely isotropic media, from travel time data. This recovery includes the tilt of the axis of isotropy as well as some of the elastic material parameters.

This is partially based on joint work with M.V. de Hoop and G. Uhlmann, and partially on the work of J. Zou.

4:00pm **Nikolai Shapiro** *Institut de Physique du Globe de Paris, Université Grenoble-Alpes*

Seismology Beyond Earthquakes: Using Continuous Seismic Data for Imaging and Monitoring

Seismology has been traditionally considered as science about earthquakes and based on signals generated by earthquakes. The rapid development of digital seismographic networks and availability of high-quality continuous seismological records resulted in change of this paradigm. A new family is seismological methods based on ambient seismic noise has emerged to image the interior of the Earth. Another important challenge in seismology is to explore weak signals generated by physical processes that occur during the preparation phases preceding major earthquakes and volcanic eruptions and recorded by continuously operating seismic networks.

4:45pm **Sella Nevo** *Google Research*

Tackling Challenges in Flood Forecasting with Machine Learning

Floods are one of the most common and deadly natural disasters on the planet. Yet, providing even basic actionable forecasts for floods globally remains a challenge, due to data scarcity, considerable manual calibration requirements, and the high computational costs of accurate high-resolution simulations. Machine learning is naturally poised to tackle these challenges but to do so we must overcome statistical, computational and representational obstacles. In this talk, I will present several ways in which machine learning methods are being used for flood prediction at scale, highlighting both their unique contributions and their limitations.

5:45pm **Tapio Schneider** *California Institute of Technology*

Earth System Modeling 2.0: Toward Data-Informed Climate Models With Quantified Uncertainties

While climate change is certain, precisely how climate will change is less clear. But breakthroughs in the accuracy of climate projections and in the quantification of their uncertainties are now within reach, thanks to advances in the computational and data sciences and in the availability of Earth observations from space and from the ground. I will survey the design of a new Earth system model (ESM), under development by the Climate Modeling Alliance (CliMA) of Caltech, MIT, Jet Propulsion Laboratory, and the Naval Postgraduate School. The talk will cover key new concepts in the ESM, including turbulence, convection, and cloud parameterizations and fast and efficient algorithms for assimilating data and quantifying uncertainties through a three-step process involving calibration, emulation, and sampling.

Abstracts — Thursday, January 30

8:30am **David Weitz** *Harvard University*

Watching and Listening to Fracture

This talk will report very high-speed imaging of fracture induced by fluid, combined with acoustic measurements to probe the nature of the fracture. The velocity of the fracture initially moves near the speed of sound, much faster than the fluid. Later the fracture advances more slowly, but typically leads the fluid. Complimentary measurements of the strain in the solid are performed with a new optical measurement technique, Dynamic Speckle Holography, which will also be described. Analysis of the acoustic signals can be correlated with the images, and can provide insight into passive acoustic emission during fracture.

9:30am **Tamara Broderick** *Massachusetts Institute of Technology*

Fast Bayesian Discovery of Pairwise Interactions in High Dimensions

Discovering interaction effects on a response of interest is a fundamental problem across the sciences. In theory, Bayesian methods for discovering pairwise interactions enjoy many benefits such as coherent uncertainty quantification, the ability to incorporate background knowledge, and desirable shrinkage properties. In practice, however, Bayesian methods are often computationally intractable for even moderate-dimensional problems. Our key insight is that many hierarchical models of practical interest admit a particular Gaussian process (GP) representation; the GP allows us to capture the posterior with a vector of O(p) kernel hyper-parameters rather than $O(p^2)$ interactions and main effects. With the implicit representation, we can run Markov chain Monte Carlo (MCMC) over model hyper-parameters in time and memory linear in p per iteration. We focus on sparsity-inducing models and show on datasets with a variety of covariate behaviors that our method: (1) reduces runtime by orders of magnitude over naive applications of MCMC, (2) provides lower Type Iand Type II error relative to state-of-the-art LASSO-based approaches, and (3) offers improved computational scaling in high dimensions relative to existing Bayesian and LASSO-based approaches.

10:45am **Matti Lassas** *University of Helsinki*

New Deep Neural Networks Solving Nonlinear Inverse Problems

We consider a new type of deep neural network developed to solve nonlinear inverse problems. In particular, we consider inverse problems for a wave equation where one want to determine an unknown wave speed from the boundary measurements. In particular, we consider the model where the wave propagation is governed by the linear acoustic wave equation on an interval. A novel feature of the studied neural network is that the data itself form layers in the network. This corresponds to the fact that data for the inverse problem is a linear operator that maps the boundary source to the boundary value of the wave that is reflected from the unknown medium. Even though the wave equation modelling the waves is linear, the inverse problem of finding the coefficients of this equation is nonlinear. Using the classical theory of inverse problems we design a neural network architecture to solve the inverse problem of finding the unknown wave speed. This makes it possible to rigorously analyze the properties of the neural network.

For inverse problems, the main theoretical questions concern uniqueness, range characterisation, stability and the regularisation strategies for the inverse problems. We will discuss the question when a solution algorithm generalises from the training data, that is, when the solution algorithm trained with a finite number of samples can solve the problem with new inputs that are not contained in the training data. This can viewed as a new question for classical inverse problems that takes its motivation from machine learning.

The results have been obtained in collaboration with C.A. Wong and M.V. de Hoop.

11:30am **Denali Molitor** *University of California, Los Angeles*

Spotlight: Iterative Methods for Large Scale Data

11:35am **Randall Balestriero** *Rice University*

Spotlight: Accelerating Seismicity before the 2017 Nuugaatsiaq Landslide Revealed from Seismograms with Unsupervised Deep Learning

11:40am **Jesse Railo** *University of Jyväskylä*

Spotlight: Tomography through Infinite Spaces

11:45am **Francesco Chierici** *Instituto Nazionale di Astrofisica*

Tsunamis Warning and Submerged Volcanic Activity Monitoring: New Detection Techniques

An effective warning and mitigation outcome is achieved when all persons at risk are prepared to properly respond upon recognition that a potentially dangerous event is forthcoming: at the very end the efficiency of a warning system can be estimated on its success in saving lives and minimizing damages and losses. Within the number of activities and actions that must be carried out to reach this goal, the issuing of prompt and reliable warnings in the shortest possible time to civil protection agencies is a crucial step in order to start the emergency response and to reduce the risk of disaster. For instance, the issue of real time reliable information that a potentially destructive tsunami is approaching or a rapid change in volcanic dynamics is occurring are key elements of these early warning systems.

The development and testing of techniques based on the detection of hydro-acoustic signals, that travel much faster than tsunami waves, and of geodetic measurement of seafloor deformation in the case of submerged calderas can help in enhancing warning systems' capabilities and in improving hazard estimation. These methods are based on the development of new instrumentation, modeling and data analysis tools.

4:00pm **Rene Vidal** *Johns Hopkins University*

Mathematics of Deep Learning

The past few years have seen a dramatic increase in the performance of recognition systems thanks to the introduction of deep networks for representation learning. However, the mathematical reasons for this success remain elusive. For example, a key issue is that the neural network training problem is non-convex, hence optimization algorithms may not return a global minima. In addition, the regularization properties of algorithms such as dropout remain poorly understood. The first part of this talk will overview recent work on the theory of deep learning that aims to understand how to design the network architecture, how to regularize the network weights, and how to guarantee global optimality. The second part of this talk will present sufficient conditions to guarantee that local minima are globally optimal and that a local descent strategy can reach a global minima from any initialization. Such conditions apply to problems in matrix factorization, tensor factorization and deep learning. The third part of this talk will present an analysis of the optimization and regularization properties of dropout for matrix factorization in the case of matrix factorization. Examples from neuroscience and computer vision will also be presented.

5:00pm **Alexei Iantchenko** *Malmö University*

Inverse Spectral and Resonance Problems for Elastic Surface Waves

Semiclassical analysis can be employed to describe surface waves in an elastic half space which is quasi-stratified near its boundary. The propagation of such waves is governed by effective Hamiltonians on the boundary with a space-adiabatic behavior. Effective Hamiltonians of surface waves correspond to eigenvalues of ordinary differential operators, which, to leading order, define their phase velocities. In case of isotropic medium the surface wave decouple up to principal parts into Love and Rayleigh waves.

We present the conditional recovery of Lamé parameters from spectral data in two inverse problems approaches:

- semiclassical techniques using the semiclassical spectra as the data;
- exact methods for Sturm-Liouville operators using the discrete and continuous spectra, or the Weyl function, as the data based on the solution of the Gel'fand-Levitan-Marchenko equation.

We conclude with comments on using scattering resonances as the data.

6:15pm **Harsha Bhat** *Ecole Normale Supérieure, Paris*

Supershear Earthquakes and Tsunamis

Earthquake ruptures are natural disasters as a consequence of energy released from a stored system, the tectonic plates. Sometimes this energy is released so fast that the rate of this energy release can exceed one of the characteristic speeds at which this information is transmitted to the rest of the medium, namely the shear wave speed. Such rare, but more frequently observed, earthquakes are called supershear earthquakes. Supershear earthquakes involve a fault rupturing, or unzipping, at a speed faster than the shear wave speed of its host medium.

At around 5km/s. In this talk I will give some fundamental historical arguments about such ruptures, their physical nature as observed in the laboratory and finally their connection to earth observations via accelerometric and geodetic data. I will conclude by giving insights into how such earthquakes can also produce destructive tsunamis.

7:00pm **Carlos Fernandez-Granda** *New York University*

Deep Learning for Signal Processing

The first part of the talk will focus on the problem of denoising natural images. Deep convolutional neural networks trained for this task can be rendered robust to changes in noise level by removing additive terms in the architecture. Locally, the networks act linearly on the noisy image, enabling direct analysis of their behavior via linear-algebraic tools. These analyses provide interpretations of network functionality in terms of nonlinear adaptive filtering, and projection onto a union of low-dimensional subspaces, connecting the learning-based method to more traditional denoising methodology. In the second half of the talk I will describe several projects where we apply deep learning to movement identification for quantitative rehabilitation of stroke patients, estimation of time-relaxation constants in quantitative magnetic-resonance imaging, and early diagnostics of Alzheimer's disease from structural MR images.

Abstracts — Friday, January 31

8:30am **Eric Vanden-Eijnden** *New York University*

Extreme Event Quantification in Dynamical Systems with Random Components

A central problem in uncertainty quantification is how to characterize the impact that our incomplete knowledge about models has on the predictions we make from them. This question naturally lends itself to a probabilistic formulation, by making the unknown model parameters random with given statistics. In this talk I will show how this approach can used in concert with tools from large deviation theory (LDT) and optimal control to estimate the probability that some observables in a dynamical system go above a large threshold after some time, given the prior statistical information about the system's parameters and/or its initial conditions. I will also show how this approach can be used to investigate the appearance of rogue waves in deep sea and estimate both their pathway of occurrence and their likelihood.

9:30am **Jesus Ibanez** *Universidad de Granada*

A New Approach Using AI in Volcano Seismology and Forecasting Eruptions

The scientific community continues its efforts to develop Volcano Early Warning systems to alert and prepare both authorities and populations in the event of volcanic eruptions. Seismology, providing superior temporal resolution, is the backbone of every volcano monitoring system worldwide. Volcano-seismic signals are generated by processes associated with magma transport and eruption; as such they contain crucial information that helps us to decipher the processes that control the occurrence, timing and magnitude of eruptions. At the present time the detection and identification of different types of volcanic events using Signal Processing and Machine Learning are crucial for Volcanic Forecasting. Eruption forecasts are based on relationships between the occurrence of seismo-volcanic signals and models of evolution of volcanic activity. However, the models available at present are only empirical. For example, the paradigm known as the Generic Swarm Model by which volcanic eruptions are preceded by swarms of earthquakes, long period (LP) or hybrid event sequences, and finally tremor is a conceptual model based on a limited set of observations. Our previous results demonstrate that ML methods, based on Deep Learning formulations jointly with Signal Processing techniques, can detect and classify volcano-seismic signals to develop more complete catalogues and more accurate earthquake classifications. These procedures require large training datasets of segmented and labelled data. However, when training is performed for a given volcano, the outcome cannot easily be generalized or transferred to other volcanic systems. In addition, when a volcano exhibits unrest, several processes occur simultaneously and at the same location, producing a suite of overlapping signals in the raw seismic record. Currently this labelling process is performed using established, albeit non-uniform criteria. The non-uniform application of criteria frequently causes confusion when different volcanic scenarios are compared. Moreover, the labels are often linked to specific seismic source mechanisms, and therefore contain implicit assumptions about the cause of unrest and its likely evolution. At the same time, one type of signal may be explained by different source processes in different volcanic environments, causing issues with the exportability of the physical models.

Our new proposed approach for the analysis of volcano-seismic data aims at forecasting volcanic eruptions by analyzing continuous volcanic-seismic signals rather than isolated events to create a new parametric database. Correlating parameter evolution with volcanic processes will advance the analysis of seismo-volcanic signals, improve the management of volcanic crises, and provide reliable tools for forecasting volcanic eruptions. Continuous seismic data can be analyzed independent of the apparent occurrence of any particular seismic events. Analyzing continuous seismic signals associated to different volcanic episodes at selected volcanoes, both that culminated and did not culminate in eruptions, enables the generation of an "Inventory of Case Studies". Our methodology comparing eruptive and non-eruptive cases is critical to obtaining a true statistical base to forecast future eruptions.

10:45am **Lauri Oksanen** *University College London*

Finite Element Methods for Unique Continuation

Unique continuation is a powerful tool in the theory of inverse problems for hyperbolic partial differential equations. For example, it can be used to solve the inverse coefficient determination problem for the acoustic wave equation, where a spatially varying speed of sound is to be determined in a body given data corresponding to acoustic measurements on the boundary of the body. Several inverse source problems can also be analyzed using unique continuation, an interesting example being the recovery of a source modeling a seismic rupture. However, our present theoretical understanding of these problems does not translate straightforwardly to practical algorithms. One reason for this is that unique continuation is understudied from computational point of view. We will discuss a recent computational approach to unique continuation based on stabilized finite element methods.

This work is based on joint work with E. Burman and A. Feizmohammadi.

11:30am **Leonardo van der Laat** *Universidad de Costa Rica*

Spotlight: Analysis of Seismovolcanic Activity During Quiescent Pre-eruptive Periods at the Turrialba Volcano

11:35am **Luca Ratti** *University of Helsinki*

Spotlight: Classic Regularization Theory of Inverse Problems Inspires Neural Network Architectures

11:40am **Daniel Gutiérrez** *Universidad de Costa Rica*

Spotlight: Using Machine Learning for Studying Fault Physics

11:45am **Paul Johnson** *Los Alamos National Laboratory*

Machine Learning Identifies Universal Fault Friction Characteristics

Cascadia, located in the Pacific Northwest of the US and western Canada, is characterized by a broad subduction zone where the Juan de Fuca plate subducts beneath the North American Plate. The fault hosts megaquakes with approximately 500-800-year repeat times in what is known as the "locked zone" of the fault. Deeper along the fault interface in the region where temperatures are such that the material acts in a ductile manner, the slowly slipping fault driven by tectonic forces, emits a long-duration signal with no characteristic compressional, shear or surface wave. This process is the result of the over-riding North American plate being dragged progressively downward by the subducting Juan de Fuca plate. Then, about every 13 months, the North American plate essentially decouples and lurchers backward toward the ocean in what is known as a "slow slip event". Slow slip event durations are order several weeks to months, and tremor is particularly evident during the slow slip events. The slow slip is identified by Global Positioning Satellite (GPS) stations located on Earth's surface that displaces laterally depending on whether or not a slow slip event is taking place at 10s of km depth.

We develop a convolutional neural network using catalogued Earth tremor data recorded on Vancouver Island in Cascadia, applying a single seismic station. Once trained, validated and tested, we find that the tremor takes place much more frequently than previously thought. Indeed, it occurs every hour of every day and reflects the movement of the subducting slab. Tremor is most apparent during slow slip events when it increases in intensity, as we knew already. Tests of generalization then were applied. The trained model was applied to data from other seismic stations located on Vancouver Island where it also identified tremor at all times. The trained model was then applied to other subduction zones including Chile, New Zealand and Japan and found to identify tremor signals in all locales. It was also applied to a very different faulting type – a transform fault in California – the famous San Andreas Fault at Parkfield. The model did a good job of identifying tremor there as well. The results suggest that friction characteristics of faults may be universal. This is something we hypothesized may be true but had little evidence for, previously.

4:00pm **Victor Schmidt** *Mila*

Deep Generative Approaches to Help Mitigate Climate Change

As IPCC reports pile up and extreme events related to Climate Change become more frequent and violent, the Artificial Intelligence community must contribute more than ever to its mitigation. In this talk, I will present my current research, composed of three projects focused on complementary approaches to fighting Climate Change with AI: Helping people better understand the consequences of Climate Change through personalized and localized visualizations of potential extreme events using Generative Adversarial Networks to help better model the low cloud distribution on earth, quantifying and limiting the carbon emissions of our communitys computations.

4:45pm **Joonas Ilmavirta** *University of Jyväskylä*

The Geometry of Anisotropy

Anisotropy is a difficult feature to model and measure but important to understand. Many of the mathematically proven results about unique determination of material parameters from surface measurements only apply to isotropic media or allow a very narrow class of anisotropy. To be able to measure anisotropy, the model has to be general enough to include that but tractable enough to give good results. I will explain how this balance can be reached with a geometrical approach, viewing the material parameters as geometry.

5:30pm **Anthony Várilly-Alvarado** *Rice University*

Cloud Storage Applications of Algebraic Surfaces via Coding Theory

Coding theory is a subject at the intersection of Computer Science, Electrical Engineering, and Mathematics. It deals with problems arising from transmitting data through noisy channels, and data storage in large-scale distributed systems (e.g., images and videos in social media). I will explain some of the basic mathematical ideas behind code design, and I will say a few words about how one can use the geometry of high-dimensional spaces to construct codes suitable for large-scale storage applications.