BWC: Bob Wright Center, U Victoria
ELL: Elliott Building, U Victoria

Buildings - Search - University of Victoria

May 25, 2026

8:15-8:45 Conference Check-in (BWC A104 Lobby)

8:45-9:00 Welcome speech (BWC A104)

9:00-10:00 Plenary talk (50 minute talk + 10 minute questions) Room: BWC A104

Julie K. Lundquist (Johns Hopkins University)

Title: Modeling the atmospheric boundary layer for wind energy

Abstract: As the world moves away from fossil fuels and towards more renewably-generated electricity, important challenges in boundary-layer meteorology become more prominent and urgent. In this talk, I will first survey some of the "Grand Challenges" of wind energy related to boundary-layer flow and turbulence. I will then delve into how recent rapid advances in observational capabilities (i.e. scanning lidar) and simulation capabilities (i.e. nested mesoscale-large-eddy simulations) are opening opportunities for new insights in boundary-layer meteorology, moving away from idealized conditions and grappling with realistic heterogenous flow conditions. Fusing advances in modeling and observation together can optimize how we design and conduct field experiments to answer critical scientific questions. We have developed a virtual lidar approach and integrated it with nested mesoscale-large eddy simulations to investigate atmospheric boundary layer phenomena. This talk will highlight our investigations of wind turbine wakes and their behavior in complex terrain (Robey and Lundquist, 2024) as well as whether or not stable boundary layer phenomena such as upwind blockage can be assessed with current measurement capabilities (Sanchez Gomez et al. 2022), related to the Perdigão and AWAKEN field experiments. This open-source virtual lidar tool, coupled with modeling atmospheric flow, can provide a means for assessing measurement capabilities in advance of measurement campaigns.

10:00-10:30 Coffee Break (BWC A104 Lobby)

10:30-11:40 Invited session (Block 1) : Stochastic modeling of atmosphere, and applications to energy and environment-Part 1: Wind and Solar **(Chair: Tylar Jia) (BWC A104)**

10:30-11:05 Invited talk (30 minute talk+5 minute questions)

Ahmed Aziz Ezzat (Rutgers University)

Title: Statistical Deep Learning for Ultra-Scale Offshore Wind Energy Forecasting

Abstract: To unlock access to stronger winds, the offshore wind industry is advancing toward significantly larger and taller wind turbines. This massive upscaling motivates a departure from wind forecasting methods that traditionally focused on a single representative height. To fill this gap, we introduce a statistical deep learning method which jointly models the offshore wind speeds across space, time, and height. Tested on real-world data from offshore wind energy areas in the Northeastern United States, the wind speed and power forecasts from DeepMIDE are shown to outperform those from prevalent time series, spatio-temporal, and deep learning methods.

11:05-11:40 Invited talk (30 minute talk+5 minute questions)

Julie Carreau (Polytechnique Montreal)

Title: A Probabilistic U-Net Approach to Downscaling Climate Simulations

Abstract: Climate change is intensifying the frequency and severity of extreme weather events, including floods, heatwaves, and heavy precipitation. Accurately projecting these hazards requires high-resolution climate data, yet regional climate models are computationally prohibitive, making large ensembles of fine-scale projections scarce. Statistical downscaling offers a computationally efficient alternative, and recent advances in deep learning have significantly expanded its capabilities. In this work, we introduce the probabilistic U-Net to the task of statistical climate downscaling, presenting the first application of this architecture in this domain.

The probabilistic U-Net combines a deterministic U-Net backbone with a variational latent space, enabling the model to capture aleatoric uncertainty and generate ensembles of physically consistent high-resolution realizations from a single coarse-resolution input. The architecture employs prior and posterior networks that encode axis-aligned Gaussian distributions over the latent space, with the KL divergence between them serving as a regularization term during training. At inference time, sampling from the prior yields diverse yet coherent predictions, overcoming the smoothing artifacts typical of purely deterministic, MSE-trained models.

We apply the model to downscale daily total precipitation and minimum/maximum temperatures over southern Quebec and the Canadian Maritimes, using the ClimEx ensemble dataset at approximately 12 km resolution as the high-resolution target, with inputs degraded by a factor of 16. A central focus of our study is the selection of an appropriate training objective. We evaluate four variants: WMSE–MS-SSIM with three different weighting settings ($\lambda = 0$, $\lambda = 1$, and the tuned

value $\lambda = 0.158$), and the almost fair Continuous Ranked Probability Score (afCRPS).

Our results reveal a clear trade-off between the two primary challenges in statistical downscaling: reproducing extreme events and capturing fine-scale spatial variability. The MS-SSIM variant ($\lambda = 0$) and the tuned WMSE–MS-SSIM setting ($\lambda = 0.158$) best reproduce observed precipitation return levels and tail distributions, while the pure WMSE variant substantially underestimates high-intensity events. Conversely, afCRPS achieves the closest match to the observed power spectral density across spatial scales and yields the lowest overall CRPS scores, though it tends to overestimate extremes. Temperature fields are well reproduced across all variants with only minor differences.

These findings suggest that combining afCRPS with MS-SSIM could offer a more balanced solution for practical impact studies, where both realistic extremes and fine-scale spatial detail are essential for robust climate risk assessment.

11:40-1:15 Lunch Break

1:15-2:25 Invited session (Block 2) : Stochastic modeling of atmosphere, and applications to energy and environment-Part 1: Wind and Solar **(Chair: Adam Monahan) (BWC A104)**

1:15-1:50 Invited talk (30 minute talk+5 minute questions)

Tianxia Jia (University of Victoria)

Title: Deep learning surrogates of WRF wind farm parameterization simulations for cost-efficient regional energy assessments

Abstract: Reliable wind farm prediction across multiple domains requires models that can capture complex interactions among atmospheric forcing, turbine layout, and wake effects, while also quantifying predictive uncertainty. Deep learning provides an efficient surrogate modelling approach for learning these relationships from simulation or observational data. In this talk, I present a multi-domain framework for wind farm power prediction using both deterministic and probabilistic deep learning models. Spatially structured architectures are used to model layout-dependent wind farm responses, while diffusion-based generative models are used to produce ensemble predictions for uncertainty quantification. The framework is evaluated across diverse wind farm domains to assess both predictive accuracy and the ability to represent uncertainty. This work demonstrates that deep-learning surrogates can enable rapid and cost-effective evaluation of candidate wind farm layouts, while also supporting uncertainty-aware planning-stage assessment.

1:50-2:25 Invited talk (30 minute talk+5 minute questions)

Kiri Daust (BC Ministry of Forests)

Title: Improvements to Multivariate GAN-based Climate Downscaling
Abstract: Accurate local-scale climate information is important for ecological applications and climate adaptation strategies. Recently, deep learning has been successful at increasing the resolution of digital images, and it shows promise as a statistical downscaling method for highly non-Gaussian climate variables. Specifically, stochastic Generative Adversarial Networks (GANs), which can be trained on pairs of low- and high-resolution climate fields, can downscale by sampling from the high-resolution distribution conditional on low-resolution fields.

Previous work demonstrated success in multivariate downscaling of wind components but encountered challenges when extending to a broader set of climate variables. Here, we investigate architectural adaptations to improve multivariate stochastic GAN downscaling. We show that introducing variable-specific output heads within the convolutional network yields high-quality downscaled fields while substantially improving inter-variable dependence structures compared to univariate approaches.

Given these improvements in both physical consistency and computational efficiency, multivariate stochastic downscaling using GANs represents a promising pathway toward operational applications, particularly for derived metrics such as fire weather indices.

2:25-3:15 Coffee Break (BWC A104 Lobby)

3:15-3:35 Contributed talk (15 minute talk+5 minute questions) (BWC A104)

Ali Hamidoglu (University of Alberta)

Title: Coalition-Based Game-Theoretic Optimization for Sustainable Power Grid Transition: Evidence from Canada

Abstract: This study develops a novel mathematical framework integrating cooperative game theory and metaheuristic optimization to model the transition toward sustainable power grids. Focusing on a Canadian case study, the model captures strategic interactions among key energy stakeholders, moving beyond conventional passive-system approaches. Results show that coalition formation, coordinated policy design, and renewable integration are critical to achieving economic efficiency and grid stability. The framework offers a scalable, policy-relevant tool for accelerating low-carbon energy transitions.

3:35-3:55 Contributed talk (15 minute talk+5 minute questions) (BWC A104)

Adel Mohammedpour (University of Calgary)

Title: Model-Free Prediction of Multivariate Time Series: A Nonparametric Approach

Abstract: This paper extends a model-free prediction framework from univariate to multivariate time series. We show that, under a mild finite-moment condition, a multivariate time series admits a VARMA-type representation and an associated infinite-past linear representation. These results are obtained without assuming that the observed data are generated by a parametric VAR, VARMA, or other specifically postulated stochastic model. Motivated by this representation, we develop a practical forecasting method based on truncating the infinite-past representation and estimating the resulting coefficient matrices by multivariate least squares. The proposed procedure is simple to implement and can be used for stationary or nonstationary, linear or nonlinear multivariate time series. We also describe recursive multi-step forecasting and discuss large-sample properties of the estimator. Simulation results and benchmark comparisons indicate that the method is competitive with standard linear forecasting approaches while retaining the conceptual advantage of a model-free formulation.

3:55-4:45 Concluding Discussion (BWC A104)

May 26, 2026

9:00-10:00 Plenary talk (50 minute talk + 10 minute questions) (BWC A104)

Jen Beverly (University of Alberta)

Title: Wildfire modeling: data and methodological considerations

Abstract:

In this overview presentation, we will explore a range of common approaches and methods used in wildfire modeling. Fundamental assumptions and considerations related to temporal and spatial scales will be reviewed. Data and methodological limitations associated with stochastic and deterministic modeling methods used in landscape fire assessments will be highlighted with case examples.

10:00-10:30 Coffee Break (BWC A104)

10:30-11:40 Invited session (Block 1) : Stochastic modeling of atmosphere, and applications to energy and environment-Part 2: Wildfires, smoke and air pollution **(Chair: Ruth Digby) (BWC A104)**

> **10:30-11:05 Invited talk (30 minute talk+5 minute questions)**
>
> **Kerry Anderson (Environment and Climate Change Canada, Emeritus)**
>
> **Title:** Mathematical problems and approaches in fire and smoke emissions research
>
> **Abstract:**
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> Fire and smoke emitted from fires is a multi-disciplinary problem. These include forestry, meteorology, and combustion science – all requiring mathematical and statistical modelling. This presentation covers some of the current mathematical problems in fire and smoke emissions research. Topics presented include fire growth and associated emissions with growth, and fire occurrence prediction.
>
> **11:05-11:40 Invited talk (30 minute talk+5 minute questions)**
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> **Mina Deshler (University of British Columbia, Vancouver)**
>
> **Title:** Assessing Wildfire Threats to British Columbia’s Electric Grid: Developing a Probability Model Based on Fire Regimes

Abstract:

The goal of this study is to create a probable maximum fire weather risk index for British Columbia's electric grid through the development of a wildfire probability model trained on historical fire spread data and ERA5 weather input. An initial verification of fire regimes types in British Columbia has been conducted using ignition data from the Canadian Wildland Fire Information System for 2014-2023. Stepwise regression was then employed to identify the key weather variables that drive fire behavior in each fire regime. These key weather variables inform the development of a machine learning model that estimates the spatial probability of wildfire spread to produce a risk map for a given fire season. CMIP6 climate scenarios are applied to the model to assess potential changes in the wildfire outlook for future seasons. Future work will incorporate BC Hydro outage data to help inform grid hardening efforts.

11:40-1:15 Lunch Break

1:15-3:00 Invited session (Block 2) : Stochastic modeling of atmosphere, and applications to energy and environment-Part 2: Wildfires, smoke and air pollution **(Chair: John Braun) (BWC A104)**

1:15-1:50 Invited talk (30 minute talk+5 minute questions)

Cyndi Whaley (Canadian Centre for Climate Modelling and Analysis)

Title: Modelling of lightning, wildfires, and plume rise in a changing climate: Insights from CanESM

Abstract:

Wildfires and lightning are inherently stochastic processes that play a critical role in shaping atmospheric composition, air quality, and climate. Accurately representing their variability and response to climate change remains a key challenge for Earth system models. In this study, we present simulations from the Canadian Earth System Model (CanESM), which includes interactive parameterizations of lightning, fire occurrence, and fire plume rise.

We focus on both the physical representation of these processes and their stochastic variability as captured through a five-member ensemble, each initialized with distinct random perturbations. This framework allows us to quantify the role of internal variability in simulated burned area and plume heights, in addition to the forced response to climate change.

Model results are evaluated against historical observations, demonstrating the model's ability to capture large-scale patterns of fire activity and plume height distributions. We then examine future projections, highlighting changes in burned area and plume injection heights under a warming climate, including insights into the uncertainty and variability gained from the ensemble approach and inherent in wildfire–atmosphere interactions.

1:50-2:25 Invited talk (30 minute talk+5 minute questions)

Sarah Henderson (University of British Columbia, Vancouver)

Title: The health effects of wildfire smoke: Established and emerging evidence

Abstract:

Wildfires and their air quality impacts have gotten progressively severe in British Columbia (BC) and across Canada over the past 20 years, and evidence suggests these trends will continue into the decades ahead. Like many fire-affected regions, BC has a long history of conducting high quality research on wildfire smoke exposure, its health effects, and effective interventions. This presentation will cover the established and rapidly evolving evidence with a focus on past and future work in BC. It will explore different exposure assessment tools, epidemiologic approaches, and critical evidence gaps.

2:25-3:00 Invited talk (30 minute talk+5 minute questions)

Ladan Tazik (University of British Columbia, Okanagan)

Title: Modeling wildfire spread as a stochastic hazard process using satellite-derived time series

Abstract:

Wildfire spread is inherently stochastic, driven by complex interactions between weather, fuel, and topography. However, most existing approaches, ranging from physics-based simulators to deep learning segmentation models treat fire progression as a largely deterministic process, often producing a single predicted outcome without explicitly quantifying uncertainty.

Recent advances in remote sensing have led to an unprecedented availability of satellite imagery and environmental data, while deep learning methods have shown promise in capturing complex spatial patterns in wildfire dynamics. Despite these developments, modeling approaches still largely focus on predicting fire extent rather than representing the underlying uncertainty in how fires evolve.

In this work, we propose a hazard-based survival modeling framework for wildfire spread that treats ignition at the pixel level as a time-to-event process. Using satellite-derived time series and auxiliary environmental variables, we construct pixel-level event datasets and model the probability of burning as a function of time-dependent covariates. This formulation enables direct estimation of ignition hazard and cumulative burn probability, providing a probabilistic and interpretable representation of fire dynamics

3:00-3:30 Coffee Break (BWC A104 Lobby)

3:30-3:50 Contributed talk (15 minute talk+5 minute questions) (BWC A104)

Aditya Bhartia (University of Alberta)

Title: Beyond Plant-Based: Efficiency-Driven Diet Optimization Reveals a Low-Emission Omnivorous Frontier

Abstract: Global food systems contribute over 25% of greenhouse gas (GHG) emissions, yet dietary policies have historically prioritized nutrition over environmental impact. Livestock production drives most emissions, whereas plant-forward options typically deliver greater nutrition per environmental cost. However, simple dietary shifts often overlook the non-linear trade-offs between specific nutritional requirements and carbon intensities, leaving a disconnect between health and climate goals. The challenge is identifying actionable diets that are both nutritionally sufficient and environmentally sustainable. Here, we show that applying Data Envelopment Analysis identifies a frontier of high-efficiency foods, generating diets that reduce carbon footprints by up to 39% relative to WHO benchmarks while meeting macronutrient targets. Unlike the binary plant-vs-omnivore framing dominant in the literature, our lowest-emission diets incorporate efficient animal protein, such as poultry. This demonstrates that sustainability does not necessarily require the complete elimination of animal products. Furthermore, compared with surveyed Canadian dietary patterns, these optimized diets achieve an 11% GHG emissions reduction alongside improved nutritional profiles. These findings illustrate that multi-criteria efficiency frameworks can bridge the gap between human health and climate goals. This approach offers a tractable, data-driven pathway to guide population-level transitions toward sustainable food systems.

3:50-4:40 Concluding Discussion (BWC A104)

May 27, 2026

9:00-10:00 Plenary talk (50 minute talk + 10 minute questions) (BWC A104)

Audun Botterud (MIT)

Title: Towards Zero-Carbon: Challenges and Solutions in Modeling Electricity Systems and Markets

Abstract: The electric power system stands at the center of the transition towards cleaner energy resources in many parts of the world. Weather-driven renewable energy is meeting a larger share of our electricity needs. At the same time, electricity demand is increasing due to electrification efforts and the rapid growth of datacenters. We demonstrate how mathematical modeling can provide insights into complex electricity systems and markets. We discuss how to represent energy storage in grid optimization models, accounting for inter-temporal dynamics and degradation effects. We illustrate how analytical results of a simple capacity expansion problem can provide insights into price formation and revenue sufficiency for wind, solar, and energy storage under long-run equilibrium conditions. Finally, we demonstrate the use of large-scale optimization to identify viable decarbonization pathways, to assess the importance of transmission in zero-carbon systems, and to evaluate cost and reliability effects of different transmission policies. We conclude by identifying research directions to better inform planning, operations, policy, and market design in future electricity systems and markets.

10:00-10:30 Coffee Break (BWC A104 Lobby)

10:30-11:40 Invited session (Block 1) : Decision making for power systems with renewables, electric vehicles and storage **(Chair: Zhirui Liang) (BWC A104)**

> **10:30-11:05 Invited talk (30 minute talk+5 minute questions)**
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> **Yize Chen (University of Alberta)**
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> **Title:** Laxity as the Guide: Enabling Reliable and Grid-Interactive Reinforcement Learning for HVACs and Data Centers
>
> **Abstract:** Demand flexibility plays a vital role in maintaining grid balance, reducing peak demand, and minimizing grid operational costs. Given their highly shiftable load and significant contribution from HVACs and modern AI data centers, they can

provide valuable demand flexibility to the power systems by adjusting their power consumption in response to electricity price or power system needs. To exploit such a flexibility, it is imperative to accurately model, aggregate, and control the load flexibility of a large population of HVAC systems and AI queries. In this talk, we tackle the curse of dimensionality issue in modeling and control by utilizing the concept of laxity to quantify the emergency level of each operation request. We further propose a two-level approach to address energy optimization, where the lower level involves an aggregator to aggregate load laxity information and use least-laxity-first (LLF) rule to allocate real-time power for individual systems based on the controller's total power. Due to the complex and uncertain nature, we leverage a reinforcement learning (RL)-based controller to schedule the total power based on the aggregated laxity information and electricity price. Proposed approach outperforms the model-based energy management and scheduling heuristics in terms of algorithm complexity, energy savings, and grid reliability.

11:05-11:40 Invited talk (30 minute talk+5 minute questions)

Dirk Lauinger (MIT)

Title: The Value of Storage in Electricity Distribution: The Role of Markets

Abstract: Electricity distribution companies deploy battery storage to defer grid upgrades by reducing peak demand. In deregulated jurisdictions, such storage often sits idle because regulatory constraints bar participation in electricity markets. Here, we develop an optimization framework that, to our knowledge, provides the first formal model of market participation constraints within storage investment and operation planning. Applying the framework to a Massachusetts case study, we find that market participation delivers similar savings as peak demand reduction.

11:40-1:15 Lunch Break

1:15-3:00 Invited session (Block 2) : Decision making for power systems with renewables, electric vehicles and storage **(Chair: Deniz Sezer) (BWC A104)**

1:15-1:50 Invited talk (30 minute talk+5 minute questions)

Zhirui Liang (University of Calgary)

Title: Toward Efficient Integration of Grid-Edge Flexibility in Voltage Regulation

Abstract: This talk addresses the challenges of integrating grid-edge Distributed Energy Resources (DERs) for voltage regulation in modern distribution systems. With increasing DER penetration, Distribution System Operators (DSOs) face issues such as uncertainty and limited visibility. DER Aggregators (DERAs) can mitigate these challenges by coordinating DERs for market participation and ancillary services, including voltage regulation. However, the role of DERAs in voltage regulation remains underexplored. We compare two approaches for procuring flexibility from DERAs: a market-based method, where the DSO and DERAs make decisions simultaneously through price signals, and an incentive-based method, where the DSO leads by offering incentives. Using game theory, we analyze the efficiency of each approach, examining equilibrium outcomes, social welfare, and the impact of deviations from ideal conditions. The study provides a detailed theoretical and numerical comparison, offering insights into which procurement method better supports voltage regulation. Our findings contribute to the design of more effective grid-edge management strategies, enhancing DSO-DERA coordination for voltage regulation.

1:50-2:25 Invited talk (30 minute talk+5 minute questions)

Chaoyue Zhao (University of Washington)

Title: A Markov Decision Process Framework for Enhancing Power System Resilience during Wildfires under Decision-Dependent Uncertainty

Abstract: Wildfires pose an increasing threat to the safety and reliability of power systems, particularly in distribution networks located in fire-prone regions. To mitigate ignition risk from electrical infrastructure, utilities often employ safety power shutoffs, which proactively de-energize high-risk lines during hazardous weather and restore them once conditions improve. While this strategy can result in temporary load loss, it helps prevent equipment damage and wildfire ignition development in the system. In this talk, we develop a state-based decision-making framework to optimize such switching actions over time, with the goal of minimizing total operational costs throughout a wildfire event. The model represents network topologies as Markov states, with transitions influenced by both exogenous weather conditions and endogenous power flow dynamics. To address the computational challenges posed by the large state and action spaces, we propose an approximate dynamic programming algorithm based on post-decision states. The effectiveness and scalability of the proposed approach are demonstrated through case studies on 54-bus and 138-bus distribution systems, showcasing its potential for enhancing wildfire resilience across different grid configurations.

2:25-3:00 Invited talk (30 minute talk+5 minute questions)

Shanukie Vithana (University of Calgary)

Title: A Static Mean Field Game Framework for Optimal Renewable Energy Development

Abstract: Mean Field Game (MFG) theory provides a mathematical framework for modeling the strategic behavior of a large number of interacting agents whose individual decisions are influenced by the aggregate behavior of the population. This framework is well suited for studying decentralized investment decisions in competitive electricity markets, where the actions of individual wind farm developers collectively shape market outcomes.

We develop a static MFG formulation for optimal wind energy capacity siting in Alberta, Canada. Agents choose locations to maximize long-run revenue while accounting for spatial correlations in wind resource availability. Price formation is modeled through the Merit Order Curve, which determines generator dispatch priority based on marginal costs and links aggregate wind penetration to equilibrium electricity prices. Spatial wind dependence is incorporated through an empirically calibrated covariance structure, combining a PCA-based component estimated from historical weather station data with a parametric residual kernel, to capture realistic variability across locations.

The equilibrium investment problem can be formulated as a quadratic program, which we solve for three policy scenarios that restrict the feasible siting area: with minimal land use restrictions, with both land use and viewscape restrictions, and with transmission-constrained siting. These policy-driven land use restrictions are represented as constraints on the agents' action space, allowing us to examine their economic implications through a comparison of the MFG equilibria across policy scenarios. Our findings highlight the trade-off between regulatory land-use objectives and economic efficiency in the use of renewable energy resources and provide quantitative insights into how policy design shapes the spatial distribution and financial performance of wind investments

3:00-3:30 Coffee Break (BWC A104 Lobby)

3:30-5:00 TBA

5:30-6:30 Conference Dinner (BWC A104 Lobby)

7:00-8:00 Special Guest Lecture (BWC A104)

Judith Sayers, indigenous leader, Chancellor of Vancouver Island University, President of Nuu-chah-nulth Tribal Council

Title: First Nation Leadership in Clean Energy and Climate Action

May 28, 2026

9:00-10:00 Plenary talk (50 minute talk + 10 minute questions) (BWC A104)

Mohammad Farazmand (North Carolina State University)

Title: A mathematical journey through modeling, forecasting, and mitigation of wildfires

Abstract: Wildfires, with their increasing frequency and intensity, pose a growing risk to the environment and infrastructure, particularly in the Wildland-Urban Interface (WUI). Addressing this challenge demands coordinated effort among governments, land managers, engineers, and scientists. In this presentation, I will first provide an overview of contemporary wildfire research, focusing on practical and scientific efforts aimed at mitigating the most damaging consequences of these events. I will then highlight several mathematical challenges related to wildfires, spanning a wide range of subjects such as inverse problems, uncertainty quantification, data assimilation, dynamical systems, and mathematical modeling. I will conclude by presenting recent advances made in each of these areas for forecasting, quantifying, and modeling of wildfires.

10:00-10:30 Coffee Break (BWC A104 Lobby)

10:30-11:40 Invited session (Block 1) : Modeling of environmental extremes: Extreme value theory, Uncertainty quantification, stochastic dynamical systems **(Chair: Mustafa Mohamad) (BWC A104)**

10:30-11:05 Invited talk (30 minute talk+5 minute questions)

Robert Webber (University of California San Diego)

Title. Interpretable machine learning forecasting of El Niño

Abstract: AI-driven weather and climate models produce excellent predictions in many situations, but they are powered by typically inscrutable deep neural networks. The grand scientific challenge is to explain why AI models make the predictions they do (explainable AI, or "XAI") so that we can compare with physical theories and ultimately improve those theories. However, current XAI methods produce inconsistent results that are muddied by high-frequency spatial noise. The purpose and novelty of our work is to introduce and develop the average gradient outer product (AGOP) as a robust XAI technique that helps humans understand the physical mechanisms driving a prediction.

We show that the AGOP can beat existing XAI baselines (gradients, integrated gradients, and Shapley additive explanations) on (1) fidelity (patterns actually drive prediction), (2) robustness (patterns are robust to modeling choices or added noise), and (3) coherence (patterns are spatially smooth). Our work applies XAI to understand predictions of the El Niño-Southern Oscillation using the Zebiak-Cane model, but the AGOP XAI method will increase the usefulness of AI across geoscience.

11:05-11:40 Invited talk (30 minute talk+5 minute questions)

Di Qi (Purdue University)

Title: Reduced-order models and data assimilation for prediction and uncertainty quantification of multiscale turbulent systems

Abstract: A new strategy is presented for the statistical forecasts of multiscale nonlinear systems involving non-Gaussian probability distributions. The capability of using reduced-order models to capture key statistical features is investigated. A closed stochastic-statistical modeling framework is proposed using a high-order statistical closure enabling accurate prediction of leading-order statistical moments and probability density functions in multiscale complex turbulent systems. A new efficient ensemble forecast algorithm is developed dealing with the nonlinear multiscale coupling mechanism as a characteristic feature in high-dimensional turbulent systems. To address challenges associated with closely coupled spatio-temporal scales in turbulent states and expensive large ensemble simulation for high-dimensional complex systems, we introduce efficient computational strategies using the random batch method. Effective nonlinear ensemble filters are developed based on the nonlinear coupling structures of the explicit stochastic and statistical equations, which satisfy an infinite-dimensional Kalman-Bucy filter with conditional Gaussian dynamics. It is demonstrated that crucial principal statistical quantities in the most important large scales can be captured efficiently with accuracy using the new reduced-order model in various dynamical regimes of the flow field with distinct statistical structures.

11:40-1:15 Lunch Break (BWC A104 Lobby)

1:15-2:25 Invited session (Block 2) : Modeling of environmental extremes: Extreme value theory, Uncertainty quantification, stochastic dynamical systems **(Chair: Slim Ibrahim)**

1:15-1:50 Invited talk (30 minute talk+5 minute questions)

Rahul Agarwal (University of Calgary)

Title: Universal Precursor Signatures for Extreme Events via Recurrence-Based Deep Learning

Abstract: Extreme events, e.g. rogue waves, paleoclimate tipping points, failures in industrial machinery, are low-probability, high-impact phenomena observed across natural and engineered systems and anticipating them remains a significant challenge. Classical statistical approaches such as extreme value theory struggle to capture the nonlinear, multiscale dynamics that often precede these events, while

physics-based simulations are costly and require governing equations that are frequently uncertain or only partially known.

Recurrence analysis offers a complementary framework grounded in dynamical systems theory: as a system approaches an extreme event, its trajectory in reconstructed phase space exhibits characteristic changes in recurrence structure that appear consistently across systems with distinct underlying physics. In this talk, I will show how combining recurrence-based representations with convolutional neural networks enables precursor detection directly from observational time series, without system-specific retraining or prior knowledge of the governing equations, and discuss open questions around universality, data scarcity, and transfer to experimental datasets.

1:50-2:25 Invited talk (30 minute talk+5 minute questions)

Atefeh Mohebi (University of Victoria)

Title: Conceptual Dynamical Models for Turbulence with Persistent Correlations.

Abstract: We extend conceptual dynamical models for turbulence by replacing white noise forcing with fractional Brownian motion (fBM) with Hurst parameter $H > 1/2$, naturally incorporating long-range temporal correlations observed in atmospheric and oceanic turbulence. The model describes the interaction between a large-scale mean flow and turbulent fluctuations, with each fluctuation mode driven directly by independent fBM processes. We establish ergodicity for the system through two theoretical results: hypoellipticity via H¨ormander's condition, showing that noise propagates through the system via Lie brackets despite the degenerate noise structure, and a coercivity estimate ensuring the system returns to a bounded region. Together, these guarantee the existence of a unique invariant measure. Numerical experiments with a six-dimensional model confirm Gaussian ve-locity statistics with kurtosis $\kappa \approx 3$ in the stable regime, consistent with theoretical predictions. Compared to Galerkin truncations of Navier-Stokes equations, our approach offers significant advantages: low dimensionality (six degrees of freedom versus hundreds) and cleaner theoretical analysis, providing a tractable framework for modeling turbulent systems with memory effects.

2:25-3:15 Coffee Break (BWC A104 Lobby)

3:15-3:35 Contributed talk (15 minute talk+5 minute questions) (BWC A104)

James McCurdy (University of Calgary)

Title: From Mountains to Megawatts: A Multiscale Stochastic Model for Wind Power Variability in Alberta

Abstract: In Alberta, the Rocky Mountains funnel atmospheric flow across the adjacent plains, creating favourable conditions for wind power generation. Wind energy now accounts for approximately 12% of Alberta's net electricity production and 20% of installed capacity, representing a nearly threefold increase since 2020. As wind penetration increases, the inherent variability of wind generation poses growing challenges for power system reliability, particularly in Southern Alberta. A significant source of this variability arises from large coherent atmospheric structures that form at the foothills of the Rocky Mountains. These structures, with characteristic horizontal scales between 30 km and 200 km, can simultaneously affect multiple wind farms and are a significant driver of wind power ramp events, or rapid changes in wind power generation. We extend a stochastic dynamical system developed by Majda & Lee to analyse the energetic relationship between the mean flow and the smaller coherent structures. This multiscale framework provides a statistical basis for analyzing wind ramp behaviour, including the distribution, duration, and spatial correlation of ramp events across wind farms. NREL Wind Integration National Dataset Toolkit reanalysis data is used in a shared random effects model to predict wind ramps, demonstrating that the framework captures key statistical features of observed ramp events in Southwestern Alberta. Our results suggest that incorporating mesoscale coherent structure dynamics into planning tools can materially improve understanding of the distribution of wind power ramps, with implications for grid balancing, reserve scheduling, and the integration of higher shares of variable renewable generation into Alberta's electricity system.

3:35-3:55 Contributed talk (15 minute talk+5 minute questions) (BWC A104)

Clayton Gao (University of Calgary)

Title: Physics-aware Cluster-based Network Modelling (CNM) of Extreme Events in Turbulent Flows

Abstract: Predicting extreme, intermittent bursts in stochastically forced turbulent flows remains a grand challenge due to their non-Gaussian statistics and high susceptibility to background noise. These bursting mechanism mirrors the dynamics across many turbulent fluid systems, ranging from tropical cyclones in atmospheric flows to thermal-acoustic resonance in an internal combustion chamber. The extreme events' hard-to-predict nature and often catastrophic consequences necessitates a robust identification and mitigation framework for general turbulent dynamical systems. While current data-driven techniques, such as Cluster-based Network Modeling (CNM), successfully map kinematic topology, they often suffer from high false-alarm rates because they cannot distinguish between harmless stochastic fluctuations and catastrophic system failures. This research proposes a Physics-Aware CNM framework that solves this bottleneck by shifting the clustering feature space

from raw kinematics to thermodynamic energy transfer rates.

Using the energy-conserving Majda-Lee intermittence model as a generative testbed, this approach isolates the localized energy subspace to track large-scale production and small-scale dissipation. The framework also incorporates an L-order time-delay embedding to track the strict chronological sequence of the turbulent cascade. By extracting a historical trajectory, the framework mathematically filters out stochastically aborted cascades and isolates true extreme-event precursors. We demonstrate that these precursors exhibit a highly deterministic, sustained injection of energy from the mean flow prior to extreme dissipation. This methodology aims to bridge the interpretability gap between black-box machine learning and physical conservation laws, dramatically increasing prediction certainty and securing the extended early-warning lead times necessary for active flow control and digital twin applications.

3:55-4:15 Contributed talk (15 minute talk+5 minute questions) (BWC A104)

Ali Akbar (McMaster University)

Title: Flood Mitigation under Climate Change in UIB: Quantile-transformed attention residual Network (QT-ARN) for peak water discharge at critical junctures

Abstract: Among all the areas impacted by global warming, the glaciers of Karakoram and Indus basin are most severely impacted, causing rapid and chaotic environmental phenomena. Coupled with rapid population growth, seasonal crops irrigation, and urbanization, the water management concern is widespread. Flooding stands as a significant natural calamity, with its mitigation hinging on precise and reliable streamflow predictions. The Upper Indus Basin (UIB) in Pakistan is particularly susceptible to flood events, which have shown an increased frequency in recent years.

Due to the diverse topography of the UIB, it can be segmented into various sub regions, with the Massam region bearing a notable cumulative impact. This research utilizes hydrological and meteorological data from stations across the UIB to investigate seasonal hydro-meteorological fluctuations. A novel approach through a hybrid model is introduced, integrating Convolutional Neural Network (CNN), specifically a Quantile-transformed attention residual Network (QT-ARN). This model leverages data spanning from 1960 to 2012, collected from 17 different locations by the Surface-water hydrology project and the Pakistan Meteorological Department. The efficacy of the model is assessed using statistical metrics and the Nash-Sutcliffe Efficiency coefficient. Findings indicate that decomposition-based approaches surpass purely AI-driven models in forecasting precision. Notably, the QT-ARNN model outperforms other AI models significantly. Validation of these results includes a peak value analysis during the flood-prone months of June to September, where the model demonstrates exceptional accuracy, with a 91.3% success rate. The addition residual inception into the QTARNN enhances the temporal learning in the data enhancing the accuracy by 5.6% in flood mitigation scenarios, reflected in the statistical indices scores

between 39.3% to 32.3%. An extended study on the Mueglits river basin, Germany shows the strong generalization in application of the proposed model for the low/discharge with high fidelity in diverse geographical locations.

9:00-10:00 Plenary talk (50 minute talk + 10 minute questions) (BWC A104)

Sara Hastings Simon (University of Calgary)

Title: New questions for energy modelling in the mid-transition

Abstract: The global energy transition can be separated into two processes, the scale up of new forms of energy production and use such as renewable energy, and the retirement of existing fossil fuel-based energy systems. As we reach the period, the mid-transition, where both fossil-based and new low-carbon energy systems exist at scale they impose operational and financial constraints on each other. Toward the end of the mid-transition when fossil base systems reach the minimum viable scale new challenges will emerge with resiliency and operability. These constraints and challenges will likely require specific analytical metrics and new modelling designed to support decision making under dynamic and uncertain conditions. I will present examples of the mid-transition dynamics in the energy sector and discuss the new questions that emerge.

10:00-10:30 Coffee Break (BWC A104 Lobby)

10:30-11:40 Invited session (Block 1) Financial modeling in the face of energy transition and climate change (**Chair**: Tony Ware) **(BWC A104)**

10:30-11:05 Invited talk (30 minute talk+5 minute questions)

Michael Ludkovski (University of California Santa Barbara)

Title: Finite Player Dynamic Games for Battery Energy Storage Intra-day Dispatch

Abstract: We develop a stochastic game-theoretic model for intraday dispatch of grid-scale battery energy storage systems (BESS). We assume that each BESS operator competitively manages her state-of-charge to maximize energy arbitrage revenues, driven by the endogenized electricity price that depends on the sum of the charging rates. We characterize the Nash equilibrium of the resulting finite-player linear-quadratic stochastic differential game with common noise, obtaining closed-form representations of equilibrium feedback controls and equilibrium price both in the general heterogeneous and the simplified homogeneous BESS setting via a system of Riccati equations. We then analyze competitive effects, including the marginal externality of additional BESS entering the market, the benefit of coordination and the corresponding market power of large operators, and supply effects from hybrid-type BESS. We further study the asymptotic regime as the number of agents grows large. Our model provides a quantitative testbed to study the impact of decentralized BESS deployment on the grid and the resulting reduction in daily price spreads. This is joint work with Ruimeng Hu and Hezhong Zhang (UCSB).

11:05-11:40 Invited talk (30 minute talk+5 minute questions)

Tomasz Weron (Wroclaw University of Science and Technology)

Title: Multiple-split probabilistic forecasts of day-ahead electricity prices for BESS management

Abstract: To address the constantly growing share of renewable energy sources (RES) in the generation mix, energy producers and consumers utilize battery energy storage systems (BESS). As technology advances, these systems are becoming increasingly common. Although the main role of these installations is to ensure stability, batteries can also be used for speculation – buying energy when the price is low, storing it and then selling at a higher price. In this research, we introduce the multiple-split method with calibration window averaging to generate accurate probabilistic forecasts of day-ahead electricity prices and utilize them in data-driven trading strategies. The results obtained for the German and Spanish markets indicate that the multiple-split approach possesses a clear advantage over classical point forecasts, as well as probabilistic methods such as quantile regression or based on in-sample errors. Moreover, the approach allows one to adjust a trading strategy to the desired outcome, whether that is profit maximization or risk reduction.

11:40-1:15 Lunch Break (BWC A104 Lobby)

1:15-3:00 Invited session (Block 2) : Financial modeling in the face of energy transition and climate change (**Chair:** Leonard Olien) **(BWC A104)**

1:15-1:50 Invited talk (30 minute talk+5 minute questions)

Hamidreza Zareipour (University of Calgary)

Title: Load, Solar and Price Forecasts Error Sensitivity in Demand-Charge-Exposed Microgrids

Abstract: This talk discusses how forecasting errors affect the operating cost of a microgrid exposed to both electricity market prices and demand charges. It focuses on three key uncertainty sources (load demand, solar generation, and electricity price forecasts) and evaluates their relative importance within a common operational framework. The work first establishes which forecast type has the greatest economic influence and then investigates whether the impacts of multiple forecast errors can be understood as simple sums of individual effects or whether important interaction effects emerge when errors occur together. The talk also

explores the role of battery capacity in managing forecast-related cost exposure. In particular, it assesses whether larger storage systems only reduce baseline operating costs or also improve resilience to forecasting inaccuracies.

1:50-2:25 Invited talk (30 minute talk+5 minute questions)

Rafal Weron (Wroclaw University of Science and Technology)

Title: From biased point forecasts of electricity demand to accurate predictive distributions: Using LASSO and GAMLSS

Abstract: Electricity demand forecasts are crucial for power system operations. Market participants frequently rely on day-ahead predictions provided by Transmission System Operators (TSOs), but these can be systematically biased and - as recent studies report - may be improved using parsimonious autoregressive models. Despite the fact that many operational and economic decisions require well-calibrated uncertainty estimates, previous work has focused on point forecasts. The key question is how to derive accurate quantile and density predictions. Here we show that processing TSO forecasts with the Least Absolute Shrinkage and Selection Operator (LASSO) brings further accuracy gains and provides strong inputs for probabilistic forecasts. Drawing on ten years of data (2016-2025) from three European and North American power markets, we find that Generalized Additive Models for Location, Scale, and Shape (GAMLSS) deliver consistently better probabilistic performance than commonly used econometric and machine learning approaches. Together, these findings highlight how regularization and flexible distributional modeling can improve uncertainty quantification of electricity demand.

2:25-3:15 Concluding Discussion (BWC A104)

3:15-3:40 Coffee Break (BWC A104 Lobby)