Fields Institute's Mathematics for Climate Change (MfCC) Network
& Waterloo Institute for Complexity and Innovation (WICI)

"Math for Complex Climate Challenges" Workshop May 1 - 4, 2023

University of Waterloo - St. Jerome's University Academic Centre (SJ2)
290 Westmount Road North, Waterloo, Ontario

ANNOTATED AGENDA

DAY ONE

Time	Event & Description	Room
8:00 a.m.	Breakfast Meet-and-greet	Atrium
8:30 a.m.	Welcoming remarks ● **Kumar Murty**, Director, Fields Institute ● **Vanessa Schweizer**, Director, Waterloo Institute for Complexity and Innovation ● **Gregory Flato**, Acting Director, Climate Research Division, Environment and Climate Change Canada ● **Mark Giesbrecht**, Dean of Mathematics, University of Waterloo ● **Johanna Wandel**, Acting Dean of Environment, University of Waterloo	SJ2 1002
9:00 - 10:20 a.m.	"**The Climate System-Biophysical and Social Interactions**" *Invited talk with* **Sarah Burch**, Executive Director, Waterloo Climate Institute Dr. Sarah Burch holds a Canada Research Chair in Sustainability Governance and Innovation, and is an Associate Professor in the Department of Geography and Environmental Management, University of Waterloo. She is an expert in transformative	SJ2 1002

	responses to climate change at the community scale, innovative strategies for making progress on sustainability, and the unique contributions that small businesses can make to solving this complex challenge. She leads the international partnership-based research project TRANSFORM: Accelerating sustainability entrepreneurship experiments in local spaces, and is the Director of the Sustainability Policy Research on Urban Transformations (SPROUT) Lab. Dr. Burch holds a PhD from the University of British Columbia, and held a postdoctoral fellowship at the University of Oxford. She is currently a Lead Author of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (winner of the Nobel Peace Prize in 2007). She was elected to the Royal Society of Canada's College of New Scholars in 2017 and was named one of Canada's Top 40 Under 40TM in 2018. Her most recent book is entitled 'Understanding Climate Change: Science, Policy and Practice'.	
10:20 - 10:40 a.m.	Break (20 minutes)	Atrium
10:40 a.m. - 12 p.m.	"**Understanding Cross-Scale Systems and Feedbacks**" *Invited talk with* **Francis Poulin**, Professor (Applied Mathematics), University of Waterloo Professor Francis Poulin received his Ph.D. in 2002 from MIT. After working as a post-doctoral and research fellow at MIT, University of St. Andrews and Scripps Institution of Oceanography, he joined the University of Waterloo as an Assistant Professor in 2004. He currently holds the position of a Professor with tenure in the Department of Applied Mathematics at the University of Waterloo. Francis's research interests are in geophysical fluid dynamics, stochastic differential equations, biological fluid dynamics, and computational mathematics.	SJ2 1002
12 - 1:30 p.m.	Lunch & networking	SJ2 Café
1:30 - 2:45 p.m.	15 Minute talks – "**Urban Climate Challenges**"	SJ2 2003
1:30 - 1:45 p.m.	"**Individual Flood Adaptation Behaviors**" The frequency and severity of floods have increased in different regions of the world due to climate change. Although the impact of floods on human health has been extensively studied, the increase in segments of the population likely to be affected by floods in the future makes it necessary to examine the impact of adaptation measures on the physical and mental health of people and property affected by these natural disasters. In this presentation, I will present the analysis of survey data from 2925 participants, based in the province of Quebec, Canada, regarding flood coping behaviors, risk perception, severity of physical and mental health and property impacts of floods. **Bouchra Nasri**, Assistant Professor (Social and Preventive Medicine), Université de Montréal	SJ2 2003

	Professor Nasri is a faculty member of Biostatistics in the Department of Social and Preventive Medicine. Prof. Nasri is an FRQS Junior 1 Scholar in Artificial Intelligence in Health and Digital Health. She holds an NSERC Discovery Grant in Statistics for time series dependence modelling for complex data. Prof. Nasri and her team are working mainly on the development of statistical learning methods, artificial intelligence methods and mathematical models for infectious diseases and public health threats related to climate change. Prof Nasri completed a Ph.D. under the supervision of Taoufik Bouezmarni, Taha Ouarda, and Andre St-Hilaire, an MSc under the supervision of Salah El-Adlouni and Taha Ouarda at INRS-ETE on developing Statistical approaches for extremes related to Climate Changes and an Ingenieur d'etat degree (eq. MSc) in Statistics at INSEA. She also completed a postdoctoral fellowship in theoretical statistics at McGill and HEC Montreal funded by the FRQNT, CANSSI and GERAD. She has authored and co-authored several papers on time series, spatial dependence, multivariate statistics, compartmental modelling, text mining, and evidence synthesis.	
1:45 - 2:00 p.m.	**"Challenges and Opportunities in the use of Agent-based Simulation for Post-disaster Recovery Simulations"** Effective recovery from future disasters requires careful planning today. At present, pre-planning focuses largely on reducing immediate losses, with less emphasis on actions to improve the recovery process. When long-term recovery is accounted for, this is done by reviewing past disasters in other communities. While this is valuable, it cannot incorporate unique community contexts, or address important but previously unobserved challenges. Without pre-planning, decisions regarding recovery need to be taken in a chaotic post-disaster scenario, being pressured by the need to act quickly to restore some sense of normalcy. These rushed decisions may fail to comprehensively evaluate the needs of the community. Disaster recovery simulation models can provide valuable insights for planners, allowing 'what-if' scenarios to be investigated, and supplementing best practices learned from previous disasters. However, developing a detailed recovery model for a community can be a daunting task. This presentation will discuss recent developments by the author on the use of agent-based models to simulate disaster recovery in communities impacted by earthquakes, wildfires, and floods. The author has employed agent-based simulations to gain insights on potential housing shortages after disasters, the implications of resource (e.g., financing, materials, workers) constraints to equity in recovery, and to estimate population losses in post-disaster communities. This presentation will discuss recent developments and lingering challenges in the use of agent-based simulations for regional risk assessments and post-disaster recovery simulations. **Rodrigo Costa**, Assistant Professor (Systems Design Engineering), University of Waterloo Rodrigo Costa is an assistant professor of Systems Design Engineering at the University of Waterloo. Costa's research on societal and environmental systems employs probabilistic methods and agent-based simulations to examine how communities' physical, economic, and social systems interact to exacerbate disaster risk and further socioeconomic and racial inequalities. His work is at the interface between engineering and social sciences. Outside of his academic research, he collaborates with emergency managers, urban planners, resilience officers, and insurance companies to further the	SJ2 2003

	understanding of disaster risks. Costa's goal is to inform targeted interventions to reduce disaster impacts, accelerate recovery, and ensure that all of society participates in the benefits.	
2:00 - 2:15 p.m.	**“Flood Coincidence Analysis using Copula”** Efficient flood risk management is crucial for minimizing the impact of floods on communities and industries. Adopting a comprehensive approach to evaluating flood vulnerabilities and hazards is necessary to develop effective strategies that can address the complex challenges associated with floods. Peak flow values in a river basin can have catastrophic consequences, particularly when they coincide. Floods resulting from peak flows can cause significant damage to properties and infrastructure, as well as the loss of lives. Therefore, estimating joint flood risks in a region is essential, particularly in areas that experience frequent occurrences of extreme events. The present study is focused on estimating the joint flood risks due to river flow extremes in the Grand River watershed in Canada. The Grand River is a significant watercourse in southern Ontario, and its watershed is home to many communities and industries. Understanding the joint flood risks in this region is vital to the development of effective flood risk management strategies that can help to protect people and properties from the impact of floods. To estimate the joint flood risks in the Grand River watershed, state-of-the-art copula analysis is used in the study. Copula analysis is a statistical method that can be used to model the joint distribution of multiple variables. In the present study, by using copula analysis the interdependence of floods at multiple locations in the Grand River watershed is evaluated and the findings of the study will provide valuable insights into the risks associated with flooding in this region. **Poornima Unnikrishnan**, Postdoctoral Fellow, University of Waterloo Dr. Poornima Unnikrishnan is currently a postdoctoral fellow at the Systems Design Engineering Department at the University of Waterloo, Canada. She obtained her Ph.D. in Water Resources Engineering from the Indian Institute of Technology Bombay and has since then been actively involved in research in the areas of time series modeling and forecasting, machine learning, extreme value analysis, atmospheric moisture tracking, numerical modeling, probabilistic analysis, and more. Her work has been published in several peer-reviewed journals and has received recognition at various international conferences. As a researcher, she is dedicated to advancing the field of water resources and data science by leveraging advanced analytical techniques to develop data-driven solutions that address complex problems.	SJ2 2003
2:15 - 2:45 p.m.	30 Minute small group question harvesting	SJ2 2003
1:30 - 2:45 p.m.	15 Minute talks – “**Aquatic Ecosystems**”	SJ2 2007

1:30 - 1:45 p.m.	**"Climate Change Impacts and Mitigation in Coastal Ecosystems: from Tipping Points to Blue Carbon and Reserve Networks"** Aquatic systems and the health of their ecosystems are central to the sustainability of many human activities. Rivers, lakes, and oceans constitute highly connected and dynamic systems, responsible for flows of individual organisms and matter that drive global biogeochemical cycles. I will briefly review known impacts of climate changes on aquatic systems and highlight current scientific challenges that could further benefit from mathematical tools. I will more specifically discuss the problem of rising temperature leading to range shift and adaptation of species. I will also discuss changes in the connectivity and flows of material across watersheds and land-sea interfaces. I will finally present examples of catastrophic shift and efforts to improve their early detection. Ongoing climate change challenges current mathematical approaches to the study of aquatic environments as dynamic and coupled systems. I will illustrate the need to explicitly integrate climate-driven changes in the structure of networks of species interactions and of spatial flows, and in the predictability of catastrophic shifts. Such integration allows for the design of dynamic networks of marine protected areas that can adapt to shift in species distribution, and to improved early detection of tipping points in the health of natural systems. There are promising avenues for integrating this complexity into tractable models that can be validated with available data and provide operational decision tools for achieving sustainable use of aquatic ecosystems. **Frederic Guichard**, Professor (Biology), McGill University Frederic Guichard is professor of biology at McGill University in Montreal, Canada. He received his PhD in marine ecology from Université Laval in 2000 and was a postdoctoral fellow at Princeton University prior to joining McGill in 2002. His research in theoretical ecology combines applied mathematics, computational tools and field experiments for the study of nonlinear dynamics and spatial structure in ecosystems. Prof Guichard is also applying his work to conservation and more specifically to the design of marine protected areas. At the core of his research are the feedbacks between species composition and ecosystem functions driven by the transformation and movement of matter across complex landscapes. Prof Guichard is also involved in the development of research and training at the interface between biology and mathematics. He is the co-director for the Center of Applied Mathematics in Bioscience and Medicine (CAMBAM) and the co-founder of the PhD program in Quantitative Life Sciences at McGill.	SJ2 2007
1:45 - 2:00 p.m.	**"Bridging the Gap between Machine Learning and Aquatic Ecosystems"** NRC DT (Digital Technologies) is part of the Labs Canada- Atlantic Science Enterprise Center (ASEC) that integrates scientific capacities from the Department of Fisheries and Oceans (DFO) Gulf region, Environment and Climate Change Canada (ECCC) Atlantic Environmental Science Centre, Canadian Food Inspection Agency (CFIA) and the Canadian Space Agency in a high collaboration environment based in Moncton New-Brunswick. In this collaboration, DT is helping to develop models to augment global understanding of marine biology cycles and in particular the work highlighted in this presentation on dissolved oxygen level variations in estuaries. Recent machine learning models have outperformed conventional methods in many aspects, leading to a growing interest in utilizing various deep learning frameworks in the time series forecasting domain. Bridging the gap between deep learning and dynamical systems provides exciting research opportunities, as they	SJ2 2007

	could benefit each other in both theoretical and computational aspects. So in this regard, there is a need to develop novel data-driven methodologies in the intersection of machine learning and mathematics in order to effectively model the time series trajectories of the climate change data towards making more sense on how climate change is affecting different aspects of our environment, atmosphere, and oceans. Findings will be valuable input for new innovative decarbonizing and environmental remediation practices. **Guillaume Durand**, Science Lead for Laboratories Canada ASEC, National Research Council Dr. Guillaume Durand was an expert in human learning and training analytics that is now focusing on artificial intelligence for oceans and climate change. He has a strong background in computer science (Software engineering, Algorithmics, Machine Learning). He has applied his expertise to develop technologies and innovative science to enhance computer-assisted human learning and training all along his career. While at NRC, Dr. Durand has also developed expertise in creative people management that He enthusiastically assumes as a dedicated team leader of a high performing Digital Technologies team (Data Science for Complex Systems). Dr. Durand is NRC science lead for the Laboratories Canada ASEC (Atlantic Science Enterprise Centre) collaborative space where He is developing activities on low to negative carbon aquaculture in conjunction with work on related oceanic climate models.	
2:00 - 2:15 p.m.	**"Navigating Ku/Kuu (sea otter) return in Canada's Pacific Northwest: Co-producing Scenarios of the Future to Reflect on the Implications for Place-based Governance"** Sea otters (Enhydra lutris) are returning to Haida Gwaii, B.C. following their extirpation in the 19th century fur trade. However, as a keystone species, they have a profound effect on ecosystem structure and function. Potential negative effects from sea otter return on local species of value to coastal First Nations presents a governance challenge. Understanding how sea otters may affect linked social-ecological systems and how best to govern sea otter return in ways that are place-based and locally relevant requires engaging with local community members. Therefore, our objectives in this paper are: 1) to co-produce place-based scenarios of alternative futures associated with sea otter return in Haida Gwaii; and 2) to use the scenarios to examine the management and governance implications associated with sea otter return. Three key insights emerged from our analysis. First, the value of co-developing future scenarios created buy-in and provided a creative and accessible strategy to understand otter-human relations and to engage participants in discussions about sea otter management and governance. Second, the scenarios and subsequent discussions reveal a strong consensus that management actions in response to the return of sea otter must reflect Haida principles and values. Third, a range of specific management approaches are available to navigate sea otter return, including the importance of a spatially sensitive management, engaging in shared learning processes, linking management to and food security, and situating management choices within a broader commitment to Haida-led research. We conclude with suggestions for how the insights from this process about the management and governance of sea otter return can be incorporated into more formal decision-making tools and models. The incorporation of these insights into models can help centre Indigenous governance systems in deciding the future of otter-human relations.	SJ2 2007

	Ella-Kari Muhl, PhD Candidate, University of Waterloo Ella is a conservation ecologist from South Africa with interests in equity, co-production of knowledge, and the sustainable governance of marine resources. She completed her Masters in 2019 (with distinction) at the University of Cape Town where she examined the perceptions of local scientists, community members, NGOs, and the local managing authority about the rezoning of Tsistikamma marine protected area - Africa's oldest MPA - and its implications for people and ecosystems. Although born and raised in Cape Town, she has worked abroad for five years across Asia and Australia, and these experiences have led to her interest in local people, their knowledge systems and their connection to the environment. Her doctoral research aims to support ecosystem-based management in the Gwaii Haanas National Park Reserve (Haida Gwaii, British Columbia) through the collaborative development and implementation of evaluative strategies and measurement frameworks associated with governance outcomes and coastal community benefits (e.g., food security, wellbeing).	
2:15 - 2:45 p.m.	30 Minute small group question harvesting	SJ2 2007
2:45 - 3:15 p.m.	Coffee break	Atrium
3:15 - 4:45 p.m.	(Round 2) 15 Minute talks – "**Climate Modelling & Emerging Artificial Intelligence and Machine Learning Approaches** "	SJ2 2003
3:15 - 3:30 p.m.	**"Combining Geophysical Models and Machine Learning"** Geophysical models such as Earth system models (ESMs), reanalysis and data assimilation systems are among the best tools climate scientists have to study the climate system and make projections of future changes. However, in addition to challenges resolving complex physical processes like cloud microphysics, these models are computationally expensive and occupy the world's largest supercomputers, necessitating trade-offs between their spatial resolution and physical accuracy. In contrast, data-driven models used in machine learning (ML) are relatively inexpensive to run, but their accuracy is limited by the quality and availability of training data. In this talk, I will present research that combines the best qualities of geophysical models and ML to target improvements in the efficiency, resolution, and accuracy of climate data. These include a novel bias-correction technique for producing regional-scale, higher resolution estimates of snow water equivalent in Ontario, a highly accurate and generalizable algorithm to retrieve accumulated precipitation from radar measurements, and an approach using a convolutional neural network to improve the computational efficiency of calibration for global ESMs. **Chris Fletcher**, Associate Professor (Geography and Environmental Management), University of Waterloo Professor and climate scientist, 20-years experience conducting research in climate and atmospheric sciences with a focus on numerical modelling and large-scale processes in cold regions like the Arctic. Contributing author to IPCC AR6 WG1 report.	SJ2 2003
3:30 - 3:45 p.m.	**"Uncertainty Estimates for Sea Ice Concentration: Results from a Bayesian Neural Network and Next Steps"** There are numerous approaches to retrieve sea ice concentration (SIC) from satellite data, but few quantify uncertainty in these SIC retrievals. For climate data records this is important because uncertainty is a piece of integrating data into probabilistic projections as well as risk assessment. One method to obtain an uncertainty estimate in a data driven problem	SJ2 2003

	(such as SIC retrieval from satellite data) is through a Bayesian neural network (BNN). In this talk we will first present motivation and results from recent experiments training and evaluating a BNN approach to estimate SIC over a full year in Baffin Bay. This region has seen significant decreases in the extent of ice cover in recent decades, which is creating stressors for local communities and wildlife. Results indicate the daily mean model error and uncertainty increase significantly during melt onset. The uncertainty is further decomposed into epistemic uncertainty (related to the model parameters) and aleatoric uncertainty (related to the data). Consistent with previous studies, the aleatoric uncertainty is much larger than the epistemic uncertainty with the ratio between these indicating where more data are needed for robust model results, and where more features may be needed. This will be followed by open research questions and challenges in the area of sea ice concentration and uncertainty estimation for climate change studies. **Andrea Scott**, Associate Professor (Systems Design Engineering), University of Waterloo Andrea Scott is an Associate Professor in the Systems Design Engineering department at the University of Waterloo. Her research focuses on data to improve model predictions. One of Professor Scott's projects involves the assimilation of remote sensing data to improve knowledge of the state of sea ice in the Arctic. More specifically, she conducts research on the assimilation of sea ice thickness and/or sea ice temperatures from visual/infrared sensors, and uses Synthetic Aperture Radar (SAR) data to estimate sea ice concentration. Other projects of Professor Scott's include the use of data assimilation to estimate parameters in turbulence models and the development of scale aware/scale adaptive parameterizations. Before working as a professor at UWaterloo, Professor Scott was a postdoctoral researcher at Environment Canada, where she was part of a team working on the assimilation of data to improve forecasts of sea ice conditions.	
3:45 - 4:00 p.m.	**"A Machine Learning-explainable AI Approach to Tropospheric Water Vapor Dynamics to uncover Changes in Climate Behavior"** Water vapor in the atmosphere plays a crucial role in the energy balance and weather, being responsible for half of the greenhouse effect. Meteorological satellites detect the water vapor and represent it on images, providing important information to understand and forecast the flow dynamics of the General Atmospheric Circulation System. A collection of computational intelligence techniques was used to investigate the structure of a large series of Meteosat (ESA) water vapor band (WV6.2) hourly images from 2009 to 2022. These techniques include the Visual Information Fidelity image quality measure, unsupervised and supervised machine learning, explainable AI methods and time series analysis oriented to uncover anomalous behavior based on Deep Learning approaches. Explainable AI methods (XAI) like Permutational Variable Importance, Local Interpretable Model-Agnostic Explanations, Shapley Additive Explanations and Ceteris Paribus profiles, were able to discover temporal variations and changes on the water vapor patterns. Outlier and anomaly detection based on techniques like CBLOF, HBOS, KNN, ECOD, LUNAR and LODA revealed important features about climate change. These findings are currently being explored and extended with respect to some outer-space processes, opening new doors, but even more complexity, to the study of climate change mechanisms. The results obtained demonstrate the great potential of ML and XAI in the domain of atmosphere dynamics and weather evolution.	SJ2 2003

	Julio Valdes, Research Officer , National Research Council Julio J. Valdes has a PhD in Mathematics and Physics. He has worked at research institutes and universities in Canada, Germany, Czechoslovakia, Spain and Cuba. Since 2001, he has been with the National Research Council Canada and is Adjunct Professor at the Universities of Ottawa and Carleton. His scientific activities cover artificial intelligence, computer science, mathematics, earth, environmental and space sciences. His topics of interest are data analytics, machine learning, computational intelligence (neural networks, evolutionary computation, fuzzy logic, probabilistic reasoning, rough sets), pattern recognition, digital image and signal processing and data visualization. He also works on computational intelligence and data analytics of earth, environmental and space sciences. He is a Senior Member of the IEEE and has conducted multidisciplinary research in a broad variety of domains covering several branches of engineering (aerospace, civil and geological), medicine and astrophysics. His record includes 310 publications in books, journals, conference papers and technical reports.	
4:00 - 4:15 p.m.	**"Universal Early Warning Signals of Phase Transitions in Climate System"** The potential for complex systems to exhibit tipping points in which an equilibrium state undergoes a sudden and often irreversible shift is well established, but prediction of these events using standard forecast modeling techniques is quite difficult. This has led to the development of an alternative suite of methods that seek to identify signatures of critical phenomena in data, which are expected to occur in advance of many classes of dynamical bifurcation. Crucially, the manifestations of these critical phenomena are generic across a variety of systems, meaning that data-intensive deep learning methods can be trained on (abundant) synthetic data and plausibly prove effective when transferred to (more limited) empirical data sets. In this talk I will present results from my recent paper in which I trained neural networks to perform Early Warning Signal (EWS) detection for lattice phase transitions. This departure from existing methods for one-dimensional time series is intended to produce classifiers better suited to spatiotemporal climate data. A model trained exclusively on 2D Ising model phase transitions is tested on a number of real and simulated climate systems with considerable success. Its accuracy frequently surpasses that of conventional statistical indicators, with performance shown to be consistently improved by the inclusion of spatial indicators. Tools such as this may offer valuable insight into climate tipping events, as remote sensing measurements provide increasingly abundant data on complex geospatially-resolved Earth systems. **Daniel Dylewsky**, Postdoctoral Fellow, University of Waterloo Daniel Dylewsky is a postdoctoral fellow in Applied Mathematics at the University of Waterloo studying machine learning methods for detection of early warning signals for critical tipping phenomena in climate systems. Daniel received his B.S. in Physics from Georgetown University in 2015 and his Ph.D. in Physics from the University of Washington in 2020, with a doctoral thesis on data-driven methods for analysis and forecasting of complex nonlinear systems. Daniel has also held research positions at the National Renewable Energy Laboratory (NREL) and at CERN.	SJ2 2003

4:15 - 4:45 p.m.	30 Minute small group question harvesting	SJ2 2003
3:15 - 4:15	"T**he Graph Model for Conflict Resolution (GMCR): Reflections on Three Decades of Development**" The fundamental design and inherent capabilities of the Graph Model for Conflict Resolution (GMCR) to address a rich range of complex real world conflict situations are put into perspective by tracing its historical development over a period spanning more than thirty years, and highlighting great opportunities for meaningful future expansions within an era of artificial intelligence (AI) and intensifying conflict in an over-crowded world. By constructing a sound theoretical foundation for GMCR based upon assumptions reflecting what actually occurs in reality, a fascinating story is narrated on how GMCR was able to expand in bold new directions as well as take advantage of many important legacy decision technologies built within the earlier Metagame Analysis and later Conflict Analysis paradigms. From its predecessors, for instance, GMCR could take advantage of option form put forward within Metagame Analysis for effectively recording a conflict as well as preference elicitation techniques and solution concepts for defining chess-like behavior when calculating stability of states from the realm of Conflict Analysis. The key ideas outlined underlying the current and projected capabilities of GMCR include the development of four different ways to handle preference uncertainty in the presence of either transitive or intransitive preferences; a wide range of solution concepts for describing many kinds of human behavior under conflict; unique coalition analysis algorithms for determining if a given decision maker can fare better in a dispute via cooperation; tracing the evolution of a conflict over time; and the matrix formulation of GMCR for computational efficiency when calculating stability and also theoretically expanding GMCR in new directions. The basic design of a Decision Support System for permitting researchers and practitioners to readily apply the foregoing and other advancements in GMCR to tough real world controversies is discussed. Inverse engineering is mentioned as an AI extension of GMCR for computationally determining the preferences required by decision makers in order to reach a desirable state, such as a climate change agreement in which all nations significantly cut back on their greenhouse gas emissions. Although GMCR has been successfully applied to challenging disputes arising in many different fields, a simple climate change negotiation conflict between the US and China is utilized to clearly explain key concepts mentioned throughout the fascinating historical journey surrounding GMCR. **Keith W. Hipel** O.C., Professor, (Systems Design Engineering), University of Waterloo Keith W. Hipel is Adjunct Professor and Distinguished Professor Emeritus of Systems Design Engineering at the University of Waterloo where he leads the Conflict Analysis Group. He is Former President of the Academy of Science within the Royal Society of Canada, Senior Fellow of the Centre for International Governance Innovation, Fellow of the Balsillie School of International Affairs, and his major research interests fall within Environmental Systems Science and Engineering. Hipel is the author or co-author of 5 books, 13 edited books, 375 journal papers, and 251 conference articles (22,503 citations; H-index = 70 i10-index = 364). Dr. Hipel is the recipient of the Officer of the Order of Canada title; Killam Prize in Engineering; Japan Society for the Promotion of Science (JSPS) Eminent Scientist Award; Joseph G. Wohl Outstanding Career Award from the IEEE Systems, Man and Cybernetics (SMC) Society; IEEE SMC Norbert Wiener Award; three Honorary Doctorate degrees (France, Hungary, Canada); Miroslaw Romanowski Medal and the Sir John William Dawson Medal (Royal Society of Canada); Ven Te Chow Award from the Environmental and Water Resources Institute, American Society of Civil Engineers; and International	

	Member designation of the US National Academy of Engineering(NAE), Foreign Academician status of the Chinese Academy of Sciences, China Friendship Award, Jiangsu Friendship Medal, Honorary Jiangsu Citizen and 5 Honorary Chinese Professorships. He is Founder and Chair of the Steering Committee of the ongoing International Conferences on Water Resources and Environment Research (ICWRER).	
4:45 - 5 p.m.	Interactive commenting & wrap up discussion *(via Miro virtual whiteboard or poster board)*	SJ2 2003

DAY TWO

Time	Event & Description	Room
8:00 a.m. 8:45 a.m.	Breakfast Meet-and-greet Welcoming remarks ● **Vanessa Schweizer**, Director, Waterloo Institute for Complexity and Innovation ● **Mallika Das**, Head of Strategy, Fields Institute	Atrium SJ2 1002
9:00 - 10:20 a.m.	"**Wetlands - Scale and Connectivity**" *Invited talk with* **Nandita Basu**, Professor (Global Water Sustainability and Ecohydrology), University of Waterloo Dr. Nandita Basu is a Professor of Global Water Sustainability and Ecohydrology, jointly appointed between the Departments of Civil and Environmental Engineering and Earth and Environmental Sciences at the University of Waterloo. She is an Editor-in-Chief of the Journal of Hydrology, Director of the Collaborative Water Program at the University of Waterloo, elected Member of the Royal Society College of New Scholars, Artists, and Scientists, and an Earth Leadership Fellow. Nandita is internationally renowned in the fields of water sustainability and ecohydrology, where her team has laid critical groundwork to address both fundamental science and applied management questions on nutrient pollution in anthropogenic landscapes. She is an environmental engineer, who uses data science, process modeling and remote sensing to explore how climate, land use, and management impacts surface and groundwater quality across agricultural, urban and forested landscapes, and from watershed to the regional and global scales. Her research leverages these insights to develop watershed management strategies that maximizes environmental benefits without significant economic costs. National and international collaboration	SJ2 1002

	has extended the reach and impact of Dr. Basu's work. She leads a $2.4M Tri-agency project that connects hydrologists, biogeochemists, ecologists and economists with stakeholders across Canada to develop approaches for managing the water quality of lake basins. She co-leads a $1.7M EU Joint Programming Initiative project to expand this work globally, connecting Waterloo with academic experts from Sweden, Denmark and Portugal. Dr. Basu has served on many advisory and technical committees, including the International Joint Commissions' Science Advisory Board – Science Priority Committee, established under the Canada-USA Great Lakes Water Quality Agreement.	
10:20 - 10:40 a.m.	Break (20 minutes)	Atrium
10:40 a.m - 12 p.m.	"**Modelling Coupled Social-Climate Systems and using Data-driven Dynamical Systems to predict Climate Tipping Points**" *Invited talk with* **Chris Bauch**, Professor (Applied Mathematics), University of Waterloo & **Madhur Anand**, Professor (Environmental Science), University of Guelph Chris Bauch is a full professor and a university research chair in the Department of Applied Mathematics. His research group develops mathematical and computational models of the dynamics of natural systems, such as ecosystems or infectious diseases. The particular emphasis is on understanding how human systems and natural systems interact with one another, and how this understanding can be used to improve ecosystem health and human health. His study systems include forest-grassland ecosystem mosaics, forest pest infestations, childhood vaccine scares, and influenza vaccination, among others (see homepage for details). His work has reached a wide public audience through the media, having been covered in The New York Times, Scientific American, USA Today, BBC News and other sources. His research has also been published in top journals such as Science and Proceedings of the National Academy of the USA. His research partners have included the World Health Organization, the United States Food and Drug Administration, and the Bill and Melinda Gates Foundation. He is also a recipient of a CIHR New Investigator Salary Award, a MRI Early Researcher Award, and a Marshall Scholarship. Madhur Anand is professor in the School of Environmental Sciences at the University of Guelph. She is an internationally recognized ecologist with research interests ranging from theoretical to empirical studies of natural and human-induced changes in ecosystems at regional and global scales and their implications for sustainability. Her research has been supported by governments, industry, national and international granting agencies and by a number of awards (e.g., Premier's Research Excellence Award, Canada Research Chairs). She has collaborated with mathematicians, theoretical physicists, statisticians, computer scientists, geographers and poets. She serves on several international journal editorial boards and grant selection panels and currently as president of the Sigma Xi Scientific Society (University of Toronto chapter). In 2011 she was named a young scientist of the World Economic Forum. She has presented scholarly work in ecopoetics, co-edited a book on ecopoetry, published poetry in literary journals and was recently elected member-at-large with the Association for Literature, Environment and Culture in Canada. Her debut collection of poems A New Index for Catastrophes, which touches on several	SJ2 1002

	complex system theory topics, was published to international acclaim in April 2015 by McClelland & Stewart/Penguin Random House Canada.	
12 - 1:30 p.m.	Lunch & networking	SJ2 Café
1:30 - 2:45 p.m.	15 Minute talks – "**Complex Coupled-human Natural Systems Modelling**"	SJ2 2003
1:30 - 1:45 p.m.	**"Simulating the Spread of Bark Beetle Infestations in Canada using Agent-based Modeling Approaches"** In Canada, bark beetles such as the emerald ash borer and the western pine beetle cause landscape-wide tree mortality. Bark beetle propagation is regulated by climate, where temperatures that exceed or fall below a certain threshold become unsuitable, thus limiting the spread and negative impact of the beetles to specific regions. However, due to climate change, increasing temperatures in the North expose healthy forested habitat to new potential bark beetle invasions. While system-level mathematical models are commonly used to simulate the spread of bark beetles over space and time, agent-based models (ABM) can be used to capture the local interactions between the individual beetles and the heterogeneous spatial environment that influences emergent patterns of spread. This talk will introduce the concept of spatial agent-based models and how they have been used to better understand, predict, and respond to bark beetle infestations in Canada in application to the invasive emerald ash borer. The insights provided from such models have the potential to support decision-making and conservation efforts aimed at measuring and mitigating the negative economic and ecological impacts of bark beetles in Canada. **Taylor Anderson**, Assistant Professor (Geography and Geoinformation Science), George Mason University Taylor Anderson is an Assistant Professor in the Department of Geography and Geoinformation Science. She received her Ph.D. in Geography at Simon Fraser University, Canada. Her research lies at the intersection of Geographic Information Science (GISc) and urban health. Specifically, Dr. Anderson investigates the role of novel data-driven modeling and simulation approaches to better explain disease prevalence, predict future trajectories of disease, and improve public health response to diseases in both ecological and human systems. These approaches have been applied to complex problems of invasive species, infectious respiratory diseases, and non-communicable diseases.	SJ2 2003
1:45 - 2:00 p.m.	**Advancing models for sustainability science: health effects of climate change** Sustainable development equitably improves wellbeing. Climate change is the critical sustainable development issue of this century, with significant potential consequences for human health. This talk will examine frontier challenges in modeling the effects of interventions and low-carbon transformations on sustainable development, with a focus on the health effects of climate change. It will present recent work from the Integrated Climate & Air Imporacts Research (ICAIR) lab, which develops novel integrated modeling methods and data-driven approaches to understand the health risks and benefits of engineering and policy responses to climate change, including mitigation and adaptation. It will focus on contributions and open challenges to frontier topics including: multi-sector impacts, uncertainty, representing human systems, and including equity.	SJ2 2003

	Rebecca Saari, Assistant Professor (Civil and Environmental Engineering), University of Waterloo Rebecca Saari is an Assistant Professor in Civil and Environmental at the University of Waterloo. A winner of the 2015 Daniel and Ava Roos Dissertation Award from MIT, Dr. Saari is an internationally recognized expert in quantifying the health and economic impacts of atmospheric emissions. Her team develops novel, interdisciplinary modelling tools of human and natural systems to analyze the health risks and benefits of engineering and policy responses to climate change, including mitigation and adaptation. Prof. Saari has given invited presentations to state-level policymakers and the U.S. EPA Climate Change Division, the U.S. EPA Health and Environmental Impacts Division, and at top institutions like Harvard, MIT, and Northwestern. She has worked with the World Health Organization to develop guidelines for research in health impacts of climate change mitigation. She is the first international member of the Scientific Steering Group of the U.S. DOE-funded MultiSector Dynamics Community of Practice. Her research contributions are documented in two dozen publications in high impact journals including Nature Climate Change. They have directly informed policies, having been requested by White House staff, cited by the U.S. Environmental Protection Agency (USEPA) administrator in the press, and used to support climate legislation in federal court.	
2:00 - 2:15 p.m.	**"Optimal Irrigation Planning via Control of Richards' Equations"** Optimal irrigation planning requires to properly model the diffusion, percolation and infiltration of water in the soil. For this purpose, the Richards' equation has proven particularly effective to describe water flows with different types of uptake and hydraulic functions, accounting for different crops or types of soil. In this talk, we propose an optimal control framework to optimize the water consumption while ensuring an efficient irrigation (and crop yield). This approach results in the boundary control of the Richards' equation with an objective functional that maximizes the root uptake while minimizing the water consumption. **Roberto Guglielmi**, Assistant Professor (Applied Mathematics), University of Waterloo Dr. Guglielmi is an Assistant Professor in the Department of Applied Mathematics at the University of Waterloo. He previously held postdoctoral fellowships at the FGV - Rio de Janeiro, Brazil; GSSI - L'Aquila, Italy; RICAM - Linz, Austria; ICL - London, UK and University of Bayreuth, Germany. He received his PhD in Mathematics at University Tor Vergata of Rome, Italy, jointly with a PhD in Applied Mathematics at the University of Lorraine - Metz, France. His research addresses problems in control and optimization of large-scale dynamics, described by ordinary or partial differential systems of evolution, with applications to the optimization of utility distribution over networks, heat transfer phenomena in the presence of crack and fractures, control of epidemics, reinforcement learning methods. He is currently a member of the Technical Committee 2.6 - Distributed Parameter Systems - of the International Federation of Automatic Control (IFAC), and he is affiliated with the University of Waterloo's Water Institute; Interdisciplinary Centre on Climate Change (IC3); Waterloo Institute for Sustainable Aeronautics (WUSA); Waterloo Artificial Intelligence Institute (Waterloo.ai); and Waterloo Institute for Sustainable Energy (WISE).	SJ2 2003

2:15 - 2:45 p.m.	30 Minute small group question harvesting	SJ2 2003
1:30 - 2:45 p.m.	15 Minute talks – "**Energy Networks; Supply Chains-design and Resilience**"	SJ2 2007
1:30 - 1:45 p.m.	"**Generative Models for Material Design in Climate Change: Overview and Applications"** In the pursuit of sustainability objectives and efforts to tackle climate change, materials have emerged as a crucial element across all areas of new technology development. From renewable energy technologies to sustainable infrastructure, carbon capture, and storage. As such the development and deployment of new materials are essential in achieving a more sustainable and resilient future. For example, renewable energy technologies such as solar panels, wind turbines, and fuel cells all rely on advanced materials with specific properties such as high conductivity, durability, and resistance to corrosion. These materials must be designed to withstand harsh environmental conditions and perform reliably for long periods of time. So in this regard, generative models have become increasingly important in material design for climate change because they allow researchers to rapidly generate and explore large datasets of potential materials with desired properties. These models generate new materials based on existing data and physical principles, such that large numbers of potential materials for specific applications can be screened quickly and efficiently. Hence, the significance of generative models lies in their ability to expedite the identification and creation of novel materials for addressing climate change concerns, through enabling researchers to rapidly generate and investigate extensive datasets of materials with desirable properties. In this talk, we will provide an overview of generative models for material design, highlighting their potential applications in climate change. We will discuss how these models work and provide examples of their use in molecular and material design technologies. We will also emphasize the potential of generative models to drive innovation in material design and accelerate the transition to a more sustainable future. **Sajjad Ghaemi**, Research Scientist, National Research Council Dr. Sajjad Ghaemi is a Research Scientist at the NRC-Fields Mathematical Sciences Collaboration Centre and an Adjunct Professor in the Department of Mathematics and Statistics at York University. He is leading AI related projects in various domains including SARS-CoV-2 vaccination and immunity modelling as a featured project in the Pandemic Response Challenge Program and generative AI models towards quantum-enhanced design for materials and chemistry. Prior to joining the NRC, he was a postdoctoral fellow at Stanford University, School of Medicine where he developed generalized linear models for learning across multiple high-throughput biological assays that were successfully implemented for a variety of bioinformatics projects. At the NRC-Fields Collaboration Centre, Dr. Ghaemi is pursuing interdisciplinary research projects such as the design of algorithms to develop applied methodologies for solving various cutting-edge and high-tech problems in science and industry, leveraging machine learning and artificial intelligence.	SJ2 2007

1:45 - 2:00 p.m.	**"Integrated Life Cycle Optimization in Chemical Process Design"** Nowadays chemical engineering design increasingly aims not only at economic but also at environmental targets. Environmental impacts of a process design are usually best qualified using the standardized, holistic method of life cycle assessment (LCA). The life cycle perspective poses a major challenge to the engineering design because the design scope expands to cover process, product, and supply chain. Here we focus on the need of an integrated assessment model particularly for process optimization where process design is coupled with the feedback loop from LCA results. This integrated life cycle optimization (LCO) approach can automate the search for optimal solutions and mitigate the risk of missing beneficial options. Particularly, early-stage evaluation of an emerging technology at low- or mid- TRLs helps identifying hotspots earlier and quantifying alternative design's benefits, thus guiding experimental research more effectively towards larger-scale tests or even commercialization. However, due to the complex and non-linear behaviours during operation, a powerful integrated modeling tool is desired for prediction and optimization for process settings and smart operation while identifying economic and environmentally benign solutions. Challenges still remain due to the lack of an effective modelling and optimization toolbox, which requires not only a precise analysis but also a fast optimization. An example of research questions from waste-to-energy technologies will be given to illustrate the needs and challenges of LCA-based process design. **Jianjun Yang**, Research Officer, National Research Council Dr. Jianjun Yang is a Research Officer at National Research Council Canada (NRC), specialized in life-cycle analysis and Techno-economic assessments (LCA/TEA) of clean technologies. She joined NRC in 2014. Since then, she has developed a standalone TEA excel tool, co-developed a multi-criteria decision analysis (MCDA) tool, and participated in multi-level LCA/TEA framework development that are valuable assets in NRC. Her past LCA/TEA experience covers high-TRL hydrogen technologies such as alkaline electrolysis and autothermal reforming with carbon capture pathways, low-TRL carbon conversion and utilization (CCU) technologies such as electrochemical and bioelectrosynthesis, as well as energy storage technologies for renewables. Working in a multi-disciplinary team environment and leading academic and international collaboration projects, Dr.Jianjun Yang's current projects are more on performing life cycle assessment on environmental impact of hydrogen production pathways and multi-objective optimization of waste-to-energy pathways. She holds a PhD in Engineering Physics from University of Saskatchewan, Canada.	SJ2 2007
2:00 - 2:15 p.m.	**"Co-benefits of integrating climate change adaptation and mitigation in the Canadian energy sector"** The integration of climate change adaptation and mitigation initiatives provides a unique opportunity for rapid progress on climate action while optimizing co-benefits. Interest in these responses to climate change are growing but more can be done to articulate how combined ends can be reached - including the limitations to integration. This presentation builds on a study of the Canadian energy sector to describe a theory of integration, mechanisms to facilitate combined outcomes, and how these lessons are being applied in other research areas related to urban infrastructure development across their lifecycles.	SJ2 2007

	Ryan Hennessey, PhD Candidate, University of Waterloo Ryan Hennessey is a Registered Professional Planner and Member of the Canadian Institute of Planners. Ryan's climate change career began in 2004 with the Canadian Centre for Climate Impacts and Adaptation Research (C-CIARN) where he worked in the Atlantic and Coastal Zone nodes. Over the past 20-years Ryan has completed and implemented climate change adaptation plans in the Yukon territory in collaboration with many Yukon First Nations, acted as the First Nation Liaison for the Energy Branch of the Government of Yukon, and was most recently a Northern Liaison for the Canadian Centre for Climate Services. Ryan has practical experience ranging from the quantitative modelling of climate impacts to the qualitative use of local and traditional knowledge across multiple sectors including agriculture and highway management. Ryan currently works with the Tr'ondëk Hwëch'in in Dawson City as the General Manager of the Tr'ondëk Hwëch'in Community Development Corporation and is a PhD Student at the School of Planning at the University of Waterloo. His current research area is focused on the co-benefits of carbon sequestration and storage and leveraging nature-based solutions along the urban-rural gradient in Canada.	
2:15 - 2:45 p.m.	30 Minute small group question harvesting	SJ2 2007
2:45 - 3:15 p.m.	Coffee break	Atrium
3:15 - 4:45 p.m.	(Round 2) 15 Minute talks - "**Urban Blue-Green Infrastructure and Urban Climate Challenges**"	SJ2 2003

3:15 - 3:30 p.m.	**"Complex Coupled-Human Natural Systems Modelling Talk"** Widely recognized as low-regret measures for disaster risk reduction and climate change adaptation, nature-based solutions (NbS) also offer climate mitigation and other co-benefits such as human mental and physical health and environmental benefits (biodiversity). Yet, NbS's integration within urban landscapes is often based on conventional monetary cost-benefit rationales, leading to misalignment between their and the actual risks' spatial distribution. In other words, economic rationales do not align with the spatially differentiated patterns of social vulnerabilities, hazard exposure, and lack of adaptive capacities. This presentation therefore asks: how can urban planning and design model complex coupled human-natural systems while accounting for both the distributive and recognitional justice in climate adaptative urban form interventions? Distributive justice refers to the equitable distribution and configuration of adaptive interventions while recognitional justice refers to proactively legitimizing difference to tackle rooted inequities. In addressing this question, I reflect on nearly a decade of empirical studies on community-based climate adaptation that I had conducted in seven different contexts: Tobago (Trinidad and Tobago), Negril (Jamaica), Amman (Jordan), Charlottetown and Toronto (Canada), ZÃ¼rich (Switzerland), and Seoul (South Korea). Specifically, I critically review the different community-based collaborative methods deployed in some of these contexts, including, among others, participatory charrettes, visually-based questionnaires, interviews, transect walks, and the deliberative Q-method. I also review the advantages and disadvantages of spatial tools (GIS, Space Syntax, and historic and contemporary maps). Through this critical reflection, I identify how cross- and interdisciplinary research is essential for equitable and just adaptation and mitigation responses, through NbS, to the climate crisis. **Luna Khirfan**, Associate Professor (Planning), University of Waterloo Dr. Luna Khirfan is Associate Professor at the School of Planning, the University of Waterloo, in Ontario, Canada. In her research, she develops coupled human-natural systems models to inform planning, policies, and behavior while accounting for justice and equity. Her work underscores the relationship between public engagement, place making, and place experience particularly, in the rehabilitation of historic cities and in adaptation to climate change. Khirfan is the author of thirty-nine peer reviewed publications and two books: "World Heritage, Urban Design and Tourism: Three Cities in the Middle East", published by Routledge in 2014 and "Order and Disorder: Urban Governance and the Making of Middle Eastern Cities" published by McGill-Queen's University Press in 2017. Dr. Khirfan is also Lead Author for the recently published Chapter 6: "Cities, settlements and key infrastructure" which is part of the Working Group II contribution to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report.	SJ2 2003
3:30 - 3:45 p.m.	**"Climate and human exposure considerations of telework"** This talk will highlight a collection of findings from approximately a dozen pandemic era studies related to building performance and human exposure, while posing some open research questions. It will include survey and field study findings of the holistic environmental impact assessments from a societal shift to telework. The impact of telework on indoor environmental quality, accessibility of blue-green infrastructure, and wellbeing will also be discussed. **Liam O'Brien**, Professor (Architectural Conservation and Sustainability Engineering), Carleton University	SJ2 2003

	Liam O'Brien, Ph.D., P.Eng. is a full professor in Civil and Environmental Engineering at Carleton University. He is the principal investigator of the Human Building Interaction Lab, which consists of a team of 15 researchers with diverse backgrounds in engineering, architecture, and psychology. His team is developing occupant-centric design processes, building code, and controls for high-performance buildings. He has authored or co-authored over 200 peer-reviewed publications and co-edited three books on high-performance building design and occupant research methods. He is heavily involved in the building design and research community, including serving as Past President of the Canadian Chapter of the International Building Performance Simulation Association and Faculty Advisor for ASHRAE. He has won several prestigious awards including the Carleton Research Achievement Award, Ontario Building Envelope Council Rising Star Award, the Ontario Early Researcher Award, and the International Building Performance Simulation Association (IBPSA) Outstanding Young Contributor Award.	
3:45 - 4:00 p.m.	**"Urban Climate Challenges Regenerative Economics to Guide Urban Environments"** Urban environments face significant challenges in mitigating climate change impacts, such as heat island effects, floods, and storm surges, aided by paved areas, high rise buildings, and a lack of green spaces. Regenerative economics, an economic model focused on creating natural capital assets, offers a potential solution to these problems. This approach aims to reduce greenhouse gas (GHG) emissions by absorbing or locking carbon into land and plants, decreasing fossil fuel use, and promoting walkable cities with better social interactions. Regenerative economics highlights the benefits of blue-green infrastructure, which combines water and vegetation elements in urban environments to mitigate climate risks and improve ecological connectivity. Examples of such infrastructure include green roofs, permeable pavements, rain gardens, individual and community vegetable gardens, and urban wetlands. By valuing natural assets like urban forests, parks, and green corridors, cities can incentivize their protection and restoration, helping them adapt to climate change, improve overall quality of life, and foster a sustainable urban future. This study explores the potential of regenerative economics to preserve and enhance urban environments, emphasizing the importance of re-evaluating traditional economic models that prioritize raw resources and often result in waste and excessive GHG emissions. Regenerative economics has overlaps with environmental and resource economics being employed to value ecosystem services and incorporate natural capital such nature-based solutions but goes beyond valuing ecosystem services and natural capital. It seeks to design economic systems that actively regenerate and enhance equitable social, ecological, and economic well-being. **Kumaraswamy Ponnambalam**, Professor (Systems Design Engineering), University of Waterloo Kumaraswamy Ponnambalam is a Professor in the Department of Systems Design Engineering at the University of Waterloo. He has previously worked at several academic institutions including the College of Engineering, Guindy in Chennai, India; the University of Toronto, the University of Ottawa, and the Technical University of Delft in the Netherlands. In the past, Professor Ponnambalam has been a Research Assistant Professor and the Associate Chair of Graduate Studies in the Systems Design Engineering department at UWaterloo. His research interests include design optimization under uncertainty, mainly pertaining to issues in civil, chemical, electrical and environmental engineering. Due to the interdisciplinary nature of the many applications, much of the work has been done in collaboration with colleagues from both within and outside the university. In	SJ2 2003

	addition, Professor Ponnambalam is also working in the Application of Intelligent Systems to hydrology and water resources, health decision making, control of satellite communications, and fault detection analysis. **Kumary Chiquinquira Ponnambalam**, Carbon Trade Economies & Regenerative Economies Researcher Kumary Chiquinquira Ponnambalam has a bachelor's degree in forest resources economics from University of British Columbia, Vancouver; master's degree in forestry economics from University of Toronto and has been writing and doing Art on Regenerative Economics	
4:00 - 4:15 p.m.	**"Geospatial Mapping of Buildings' Greenhouse Gas Emissions Distribution at City Scale using Publicly Available Data"** As the world faces climate change adaptation and mitigation challenges, many municipalities have set net-zero targets by 2050. Achieving this target requires extensive planning for natural and built environments. Municipalities need tools to assess the interaction of their land use plans in meeting net-zero targets. Here, we develop methods to support this by evaluating GHGs from buildings. We develop a geospatial GHG emission distribution model for all building types at municipal scales. We use publicly available datasets, addressing challenges in data availability, quality, and consistency with data preprocessing, including data cleaning and geocoding. Buildings are categorized based on their size and operation type, which are their most expressive features. For each category, a statistical confidence interval is then determined using real energy consumption data and presented in a lookup table. The total emissions of individual buildings are calculated and presented on a map by matching them to a category and then using emission factors reported by the government or published in the literature and the building's total floor space. In addition, Heating and Cooling degree days information is used to estimate the potential impacts of climate change in our model. This approach can be integrated into complex models of coupled human-natural systems to better understand the role of the built environment in nature-society interactions and adaptive capacity. **Amir Salehi**, Grad student, University of Waterloo Amir Reza Salehi is a researcher and engineer who is passionate about undertaking engineering and mathematical approaches toward environmental and sustainability problems. Amir holds a Bachelor of Science in Industrial Engineering from the University of Tehran and was honored to graduate as Valedictorian. Currently, Amir is a Master of Applied Science (MASc) student of Civil and Environmental Engineering at the University of Waterloo, where Amir is fortunate enough to be part of the ICAIR lab, where they study the co-benefits of climate and air policies. Amir's current research is focused on understanding the complex emission behavior of buildings under the impact of climate change and policy implementations.	SJ2 2003
4:15 - 4:45 p.m.	30 Minute small group question harvesting	SJ2 2003
3:15 - 4:45 p.m.	(Round 2) 15 Minute talks - "**Social Networks and Social Imitation/Contagion/Norm Adoption**"	SJ2 2007

3:15 - 3:30 p.m.	**"A Coupled Social-Climate Model with Country-level Structure"** Mathematical models of climate change have traditionally described anthropogenic carbon emissions as outcomes of evolving socio-economic scenarios. A drawback of this approach is that the underlying dynamics of human behaviour that are, ultimately, responsible for all carbon emissions, are ignored. So far, there exist a handful of 'social-climate' models that address this shortcoming, results from which make a compelling case for the inclusion of social and behavioural processes in models of climate change. We attempt to construct a coupled social-climate model with country-level parameterization, with the goal of adding a layer of realism, as well as the dimension of heterogeneous human behaviour. Our model features two-way coupling between human behaviour and climate change. Humans are able to influence climate change trajectories by choosing to take mitigative action; their decision to do so is determined by economic incentives and the severity of climate change impacts in their country. Individuals also dynamically learn behaviours from each other, at rates specific to the countries they live in. This process is mathematically represented using tools from evolutionary game theory. Our description of social dynamics uses parameter values inferred from survey data and studied correlations between behavioural variables and socio-economic indicators, using an approximate Bayesian method. This work offers one of many possible perspectives on the representation of heterogeneous behaviour in coupled social-climate models; we hope to explore other possibilities in the future. **Amrita Punnavajhala**, PhD candidate, University of Waterloo Amrita is a third-year PhD candidate in the Department of Applied Mathematics at the University of Waterloo. Amrita has bachelor's and master's degrees in Mathematics, and has worked, in the past, on the synchronization of chaotic systems. Amrita's present work lies in the area of coupled social-climate models - and within this, specific research interests are in the representation of heterogeneous human behaviour in these models.	SJ2 2007
3:30 - 3:45 p.m.	**"Extreme Weather Events and Climate Perceptions"** A growing body of literature has explored the relationship between weather experience and climate change related perceptions, as more people are exposed to more frequent and more severe extreme weather events as a result of climate change. Despite two decades of extensive research on this topic, the relationship remains unclear; some studies indicate that local weather experience is a driver of climate perception change, while others do not. Typically, the dependent variables consist of climate-related opinions or behaviors, such as beliefs, beliefs certainty, risk perceptions, mitigation preferences, and behaviors. The independent variables include subjective experiences, others' experiences, and objective temperature experiences (long-term and short-term temperatures, precipitations, snowfalls, droughts, and the Climate Extremes Index which combines the aforementioned factors). And a large portion of the dependent variables was measured using survey-based scales of opinions, such as "I will support a national policy to mitigate climate change" (1=Strongly disagree; 7=Strongly agree). Further research is suggested on the setting, variable choice, methodological approach, and theoretical framework. From my perspective, considering the gaps in the previous studies, I think the survey should be designed to employ data-driven questions to obtain more accurate and reliable answers on climate perceptions. And also use the realized	SJ2 2007

	behaviors as the dependent variables. Additionally, a social network analysis of social media could be used to assess some questions such as how direct and indirect extreme weather experiences influence climate perceptions. **Rui Wang**, PhD candidate, University of Massachusetts Amherst Rui Wang is a second-year PhD student in Resource Economics at UMass Amherst, who is interested in using theory, experimental methods and social network analysis to explore some environmental questions, especially climate change. Rui has recently finished a working paper which is about mechanisms to improve the cooperation of climate change negotiations and evaluate them using lab experiments. Currently, Rui is still in the topic exploration stage under the supervision of Prof. John Stranlund and Prof. Rong Rong. Rui is working on two proposals that are related to climate change topics. One is using incentive compatible methods to reveal weather and climate related beliefs and investigate people's adaptation and mitigation behaviors using field experiments. Another is about the peer effects on direct and indirect extreme weather experiences using social network analysis to analyze a large dataset of Twitter messages about climate change. In addition, Rui is working on a project which is about the technology incentives in the emissions market under a flexible emissions cap.	

3:45 - 4:00 p.m.	**"Spatial and Temporal Discounting in a Coupled Social-Climate"** This research discovers the effects on mitigation and projected temperature anomalies through applying spatial and temporal discounting in human decision making in a coupled social-climate model. While past climate models have implemented a static human contribution to climate change through Representative Concentration Pathways and Shared Socioeconomic Pathways, this research develops a dynamic social system coupled to a simple Earth System Model (ESM). Idealizing a two-way feedback between human decision making, social norms, and human behaviour with changes in the climate. The spatial and temporal discounting addressed in this research is guided by the definition of judgemental discounting, such that individuals consider climate change conditions to be worse in other locations and further in time. Discounting is introduced into utility functions through a two-patch social system (spatial) and percentage discounting per year (temporal). These utilities determine the impacts of individuals in different populations taking up mitigative or non-mitigative strategies, directly leading to replicator equations that build the social system. Coupling this to the ESM that sufficiently represents the carbon cycle and greenhouse gas effect, keeps the climate system simple to remain focused on understanding the interactions between discounting, humans, and the climate. Results are obtained through implementing the coupled feedback model with climate, social, and economic data. We hypothesize that the results will directly address the fundamental challenge in dealing with climate change: where the negative effects of climate change are often portrayed as "there and later", thus reducing the motivation to mitigate "here and now". **Mackenzie Cameron**, Grad student, University of Waterloo Mackenzie is a second year Master's student in Applied Mathematics at the University of Waterloo under the supervision of Dr. Chris Bauch and Dr. Madhur Anand. Mackenzie's research is in the area of coupled human environment systems. Currently, she is focused on modeling the interactions between human behaviour and climate change, stiving to model key barriers to mitigation.	SJ2 2007
4:00 - 4:15 p.m.	**"Examining the Influence of Rumour Propagation in Heterogeneous Social Networks on Temperature Change in a Coupled Socio-Climate Model"** Climate change rumours on social networks, propagated individually and in groups, affect people's perspectives on the problem. Individuals' attitude vastly affects the transformations we are experiencing, and is vital in mitigating or intensifying climate change. The climate changes we are experiencing are primarily due to human activities, making it essential to understand how the coupled system works. As an extension to an existing rumour propagation model in social networks, involving groups and an Earth System model, we developed a socio-climate model by coupling the rumour dynamics in heterogeneous networks with climate change. Incorporating climate dynamics into the rumour propagation model helps us analyze how rumours about climate change impact individuals' opinions when only two choices are available, either believe or reject the rumour. In our model, it is assumed that, when people experience an increase in the global temperature, they tend to reject the rumour rather than believe it. Our objective was to acquire a qualitative understanding of the coupled model and to study how rumours affect global temperature levels. In this model, rumour propagation began in 2021, and the changes in temperature levels for the next 200 years for the model are computed. The rumour rejectors limit their CO_2 emissions at a	SJ2 2007

	constant value to reduce global temperature. Initial analysis of this coupled model, using numerical simulations, indicates that the emission-limiting strategies considered by the rejectors affect the time taken to see a temperature reduction. We also found that emission-limiting value is highly influential as it can cause an increase in the global average temperature by 0.5°C. Our model indicates that parameters involved in group propagation of rumours have the upper hand in controlling temperature change, compared to individual propagation. **Athira Satheesh Kumar**, Grad student, University of Waterloo Athira Satheesh Kumar is a graduate student at the University of Waterloo. She is pursuing her PhD in Applied Mathematics. Her work focuses on developing and analyzing coupled human climate models. Her areas of interest also include developing disease and rumour models in networks.	
4:15 - 4:45 p.m.	30 Minute small group question harvesting	SJ2 2007
4:45 - 5:00 p.m.	Interactive commenting & wrap up discussion *(virtual whiteboard or poster board)*	TBD
5:00 - 6:00 p.m.	**Art Reception** **Kumary Chiquinquira Ponnambalam**, Carbon Trade Economies & Regenerative Economies Researcher See the painting titled "Cosmopolitan, Mixed Media" (size: 24 inches X 17 inches) here: https://www.kumacp.com/exhibition2 Our ancestors may be curious about the measures we plan to implement in addressing the challenges posed by urban environments, commonly known as concrete jungles, which are already impacted by heat island effects, floods, storm surges, and other related issues. Kumary Chiquinquira has a bachelor's degree in forest resources economics from UBC, Vancouver, a masters degree in forestry economics from UofT and has been writing and doing Art on Regenerative Economics. **Adrienne Mason**, Grad student, University of Waterloo My Climate Art installation consists of a number of interactive kinetic sculptures, called Holling's Hydrology Loops https://youtu.be/2fd7ADZMtks. These sculptures combine Bernoulli's Law from Hydrology regarding what makes water flow in a system, with Holling's Loop from Resilience theory that describes how an ecosystem can maintain a dynamic equilibrium state when adequate connectivity and capacity are present in a system. My exhibit stacks these Holling's Hydrology Loops from the small water cycle, at the local watershed scale, with larger hydrological systems https://youtu.be/RrIRjhiiucM such as the Great Lakes ecoregion. The artist stands on the sculpture Earth System State Water Balance https://youtu.be/zLrL6jkPnoo and manipulates the other sculptures as puppetry. All of this is to symbolize that human action drives water system function at this stage in the Anthropocene and we can choose to maintain the dynamic equilibrium that supports this current Earth System State Water Balance or we can prepare to Tip into another state that is less favourable.	Atrium

DAY THREE

Time	Event & Description	Room
8:00 a.m. 8:45 a.m.	Breakfast Meet-and-greet Welcoming Remarks ● **Blake Phillips**, Director, School of Accounting and Finance, University of Waterloo ● **Jenn Lynes**, Co-Director, Sustainability and Financial Management Program, University of Waterloo (TBC)	Atrium SJ2 1002
9:00 - 10:20 a.m.	"**Climate and Sustainable Finance**" *Invited talk with* **Olaf Weber**, Professor (Environment, Enterprise and Development), University of Waterloo Olaf Weber is a Professor at the School of Environment, Enterprise and Development. In addition, he holds the position as the University of Waterloo's Research Chair in Sustainable Finance and is Senior Fellow of CIGI. His research and teaching interests address the connection between financial sector players, such as banks and sustainable development and the link between sustainability and financial performance of enterprises. His research focus is on the impacts of the financial industry on sustainable development, the role of voluntary and regulatory mechanisms for the financial sector to become more sustainable, social banking and impact investing, the materiality of sustainability risks and opportunities for investors and artificial intelligence as a tool to analyze environmental, social, and governance (ESG) performance.	SJ2 1002
10:20 - 10:40 a.m.	Break (20 minutes)	Atrium
10:40 a.m. - 12 p.m.	"**Statistics for Complex Climate Problems**" *Invited talk with* **David Saunders**, Associate Professor (Statistics and Actuarial Science), University of Waterloo David Saunders is an Associate Professor in the Department of Statistics and Actuarial Science at the University of Waterloo, and the Director of the Centre for Financial Industries at the Fields Institute for Research in Mathematical Sciences. He is the author of many articles on the subjects of risk management, portfolio optimization and derivatives pricing, and co-author (with Prof. Mary Hardy) of the book "Quantitative Enterprise Risk Management," published by Cambridge University Press.	SJ2 1002
12 - 1:30 p.m.	Lunch & networking	SJ2 Café

1:30 - 2:45 p.m.	15 Minute talks – “**Climate Economics and Governance**”	SJ2 2003
1:30 - 1:45 p.m.	**“Academia and Industry Collaborate on Research in Mathematical Climate Finance”** Climate change, the opportunities and adverse impact it brings forth, invites academia, the industry, and governments to collaborate with a view to develop solutions which are solidly grounded in mathematical sciences. In this short talk, progress shall be reported on joint projects in mathematical climate finance developed with practitioners of the financial industry. Risk quantification and management across time scales, the need for a probabilistic framework suitable for scenario generation and statistical analysis, and a confident deployment of climate change models in stochastic settings as found, e.g., in finance and insurance, are just a mere few of the areas in which cross-disciplinary joint research in mathematical sciences is needed. **Andrea Macrina**, Professor (Mathematics), University College London Andrea Macrina is Professor of Mathematics and the Director of the Financial Mathematics MSc Programme in the Department of Mathematics, University College London. Andrea is Adjunct Professor at the University of Cape Town in the African Institute of Financial Markets and Risk Management and is a recipient of the Fields Research Fellowship. His research programme includes projects in probability, stochastic modelling, and financial and insurance mathematics with a current emphasis on mathematical climate finance. Andrea is co-editor of a book on Financial Informatics, published in 2022, containing 18 foundational articles on the information-based modelling framework. He is a regular speaker at seminars and conferences where he presents his research findings to academics and industry professionals. Andrea holds a PhD in Mathematics from King's College, University of London, and an MSc in Physics from the University of Bern, Switzerland.	SJ2 2003
1:45 - 2:00 p.m.	 The presentation will cover the investor sustainability reporting landscape, focusing on PRI's reporting and assessment framework. The presentation is split into three sections 1) Research and insights, covering the strengths of PRI reporting and opportunities for growth, the challenges faced, and insights derived from reporting data 2) Reporting feedback and changes, explaining how feedback from investors drives the ongoing development of the reporting framework 3) Data distribution development, describing how PRI unlocks value of the data and what more could be done through dashboard solutions, tools, research and data sharing. **Mikael Homanen**, Head of Product Innovation and Research, Principles for Responsible Investment Mikael Homanen is the Head of Product Innovation and Research at PRI leading the development of internal research, software and ESG data integration projects. He is also a Honorary Research Fellow at Bayes Business School in London. He has previously been a Bradley Fellow at the University of Chicago Booth School of Business, a visiting scholar at the Wharton School, University of Pennsylvania as well as Singapore Management University and has also worked as a Consultant at the World Bank’s Development Economics Research Group, Finance and Private Sector Research team.	SJ2 2003

2:00 - 2:15 p.m.	**William White**, Senior Fellow, C.D. Howe Institute William R. White is currently a Senior Fellow at the C.D. Howe Institute in Toronto, Canada. From October 2009 until April 2018, he was the chairman of the Economic and Development Review Committee at the OECD in Paris. He was for four years also a member of the Issing Committee, advising the German chancellor on G-20 issues. Mr White joined the Bank for International Settlements in June 1994 as Manager in the Monetary and Economic Department, and was appointed to the position of Economic Adviser and Head of the Monetary and Economic Department (MED), in May 1995. Mr White began his professional career at the Bank of England, where he was an economist from 1969 to 1972. Subsequently he spent 22 years with the Bank of Canada. His first six years at the Bank of Canada were with the Department of Banking and Financial Analysis, first as an economist and finally as Deputy Chief. In 1978, Mr White took on different responsibilities as the Deputy Chief of the Research Department and was made Chief of the Department in 1979. He was appointed Adviser to the Governor in 1984 and Deputy Governor of the Bank of Canada in September 1988. In addition to these permanent positions, Mr White spent six months (1985- 86) as a Special Adviser to the Canadian Minister of Finance and six years as a member of Statistics Canada's Advisory Panel on the National Income Accounts. Since the late 1980s, he has been an active participant in many international committees, including the EPC and WP3 at the OECD, the G-10 Deputies, and the Bellagio Group which brings together senior government officials, central bankers and academics. Born in Kenora, Ontario, Mr White received his BA from the University of Windsor in Windsor, Canada. In 1969 he received his PhD from the University of Manchester, UK, where he was supported by a Commonwealth Scholarship. Mr White was presented in September with the 2016 "Adam Smith Prize", the highest award of the National Association of Business Economists (US). In May of 2015 he was honoured with the "Hans-Moller-Medal" from VAC, the alumni club of political economists at Ludwig-Maximilian University of Munich. Prior to that, he received the annual "Prize of the Monetary Workshop in Monetary, Financial and Macro-Prudential Policy "in Frankfurt in May 2014. William White has in recent years published many articles on topics related to monetary and financial stability as well as the process of international cooperation in these areas. He speaks regularly to a wide range of audiences.	SJ2 2003
2:15 - 2:45 p.m.	30 Minute small group question harvesting	SJ2 2003
1:30 - 2:45 p.m.	15 Minute talks – "**Decarbonization, Carbon Currencies, and Climate Risk**"	SJ2 2007
1:30 - 1:45 p.m.	**"Decarbonization of large Financial Markets"** We build a model of a financial market where a large number of firms determine their dynamic emission strategies under climate transition risk in the presence of both environmentally concerned and neutral investors. The firms aim to achieve a trade-off between financial and environmental performance, while interacting through the stochastic discount factor, determined in equilibrium by the investors' allocations. We formalize the problem in the setting of mean-field games and prove the existence and uniqueness of a Nash equilibrium for firms. We then present a convergent numerical algorithm for computing this equilibrium and illustrate the impact of climate transition risk and the presence of environmentally concerned investors on the market decarbonization dynamics and share prices. We show that uncertainty about future climate risks and policies leads to higher overall emissions and higher spreads between share prices of green and brown companies. This effect	SJ2 2007

	is partially reversed in the presence of environmentally concerned investors, whose impact on the cost of capital spurs companies to reduce emissions. However, if future climate policies are uncertain, even a large fraction of environmentally concerned investors is unable to bring down the emission curve: clear and predictable climate policies are an essential ingredient to allow green investors to decarbonize the economy. **Peter Tankov**, Professor (Quantitative Finance), ENSAE Paris Peter Tankov is professor of quantitative finance at ENSAE, the French national school for statistics and economic administration, having previously worked at Paris-Cite university and Ecole Polytechnique. He is a mathematician, specialist in applied probability and stochastic processes. His current research interests include quantitative finance, energy finance, and green and sustainable finance. Peter is the author of over 50 research articles on these and other topics and of the widely read book, Financial Modelling with Jump Processes. He is the recipient of the 2016 Best Young Researcher in Finance award of the Europlace Institute of Finance and the principal investigator of several national grants. Peter is the scientific director of the Green and Sustainable Finance Research Program at Louis Bachelier Institute and member of editorial boards of the main quantitative finance journals: Mathematical Finance and Finance and Stochastics.	
1:45 - 2:00 p.m.	**“Extreme Climate Risks and Financial Tipping Points”** Carbon taxes are often seen as promising tools but at the risk of financially overburdening the private sector, depriving it of important economic resources. However, analyzing the financial feasibility of mitigation-adaptation policies using conventional Integrated Assessment Models (IAM) is limited, as they do not simultaneously endogenize economic growth, emissions, and damages. Here, we present IDEE (Integrated Dynamic Environment-Economic), a new IAM based on the coupling of an Earth Model of Intermediate Complexity and a non-linear macroeconomic model in continuous time. We analyze the simultaneous effects of carbon taxes and public spending, both on climate and on the world economy. We show that, above a warming about +2.3 C, damages drastically foster the need for additional investments in productive capital---an adaptation necessity---that potentially leads private firms to a debt overhang and a worldwide cascade of defaults. This suggests that the Paris Agreement target should not only be motivated by the climatic non-linearities and tipping points arising beyond the \degC{+2} threshold, but also by the emergence of financial tipping points. We also show that, provided public subsidies are high enough, a tax of US$ 300~per~tCO2-eq by 2030 enables reaching net-zero emissions in 2050, preventing firms from suffering global bankruptcy. **Gael Giraud**, Founder and Director, Environmental Justice Program, Georgetown University An alumnus of the Ecole Normale Superieure (Paris, France), Prof. Giraud is a former senior researcher in mathematical economics at the (French) CNRS and a former Chief economist of the French Development Bank. He is the founder of the Environmental Justice Program at Georgetown university and a professor at McCOurt School of Public Policy.	SJ2 2007
2:00 - 2:15 p.m.	**“Design Spaces and Choices for Carbon Currencies: Values, Robustness and Effective Dynamics”**	SJ2 2007

	Possible financial instruments for mitigating or reversing climate change comprise a vast design space of possibilities and can target different niches. In particular, crucial in avoiding pathological outcomes are the value-systems backing currency design (cf. Bitcoin's proof-of-work vs. Sardex unit's regional zero-interest decentralized mutual credit). Carbon taxes vs. carbon-credits vs. carbon currencies based on values such as carbon sequestration (e.g. of 1 ton CO_2 for 100 years or proof-of-sustainable supplantation of fossil fuels, etc.) have a range of different possible structural features, and robustness properties, e.g. against exploitation, local vs. regional vs. global possibilities, and lead to different outcomes for their resulting dynamics in socio-economic-ecological contexts. For example, carbon tax credits or surcharges are volatile as a method for creating socio-ecological economic systems for coping with or mitigating climate change - a new government or political party can abolish them at a whim; and any currencies that are too permissive in interconvertibility may be subject to extractive exploitation. Multiple designs need to be considered, modeled and evaluated: Multiscale mathematical modeling techniques for discrete and continuous dynamical systems, as well as agent-based methods, graph theoretic flow and complexity analysis, can be brought to bear on predictive and coarse-to-fine grained analysis of different currency designs in the struggle to meet climate change challenges. Policy, economic and ecological challenges demand that a critique on different interpretations of value in carbon currency design and niche targeting needs to be developed from different disciplinary traditions and perspectives in tandem with the mathematics in order to resolve the existential risks we face as a species. **Chrystopher Nehaniv**, Professor (Systems Design Engineering), University of Waterloo Prof. Chrystopher Nehaniv is a Mathematician (BSc, Univ. Michigan 1987; PhD, 1992; Univ. California, Berkeley), Computer Scientist, Complex Adaptive Systems Researcher, and is Professor in the Departments of Systems Design Engineering and of Electrical & Computer Engineering at the University of Waterloo in Ontario, Canada. Prior to coming to Canada, he was Professor of Mathematical and Evolutionary Computer Sciences at the University of Hertfordshire, UK, and involved in a number of EU Future and Emerging Technology projects including BIOMICS and Interacting Decentralized Transactional and Ledger Architecture for Mutual Credit (INTERLACE https://cordis.europa.eu/project/id/754494) lead by Sardex SPA, which created and supports a local complementary currency to the Euro. He is an active member of the Waterloo Institute for Complexity and Innovation, as well as the Canadian Network for Complex Systems.	
2:15 - 2:45 p.m.	30 Minute small group question harvesting	SJ2 2007
2:45 - 3:15 p.m.	Coffee break	Atrium
3:15 - 4:30 p.m.	(Round 2) 15 Minute talks – “**Climate Economics and Governance**”	SJ2 2003

3:15 - 3:30 p.m.	**"Some Aspects of Green Finance: Concepts and Methods"** Green Finance, aka Sustainable Finance, consists of a set of financial regulations, standards, and products that pursue an environmental objective, and facilitate an energy transition. In some cases, pillars, such as society and governance are also considered to be other important criteria for financial decision making processes. There are two distinct, and yet, at the same time, complementary aspects of green finance. The first aspect relates to the field of corporate finance, which are primarily concerned with corporate entities trying to adjust to emerging issues such as climate change, inclusion, and other growing ethical concerns. In this aspect green finance is addressed from inside of corporations with questions such as how to cope with these emerging issues or how to fund green projects. The second aspect of green finance addresses the willingness of investors to invest in green assets. In this aspect green finance is addressed from outside of corporations and inside of markets. This brief talk focuses on the second aspect of green finance. In particular we provide a state-of-the-art synthesis of integration of sustainable criteria into complex portfolio optimization and explore challenges that we are still facing at this juncture. This talk will gloss over simple portfolio solutions, then embark on discussion of solutions obtained from mean-variance allocation. We also explore other quantitative methods which resort to more complex optimization schemes beyond simple extensions of mean-variance preferences. Lastly we wrap up the talk by discussing other integration techniques used to incorporate the ESG scores into portfolio constructions. **Tony Wirjanto**, Professor (Statistics and Quantitative Finance), University of Waterloo Professor Wirjanto has a PhD in Econometrics Theory. He is a professor of Statistics and Quantitative Finance at the Department of Statistics & Actuarial Science as well as a professor in Finance at the School of Accounting & Finance, both of the University of Waterloo. He serves on the editorial boards for a number of academic journals such as Austin Statistics, Econometrics, Journal of Mathematical Finance, Journal of Risk and Financial Management and Mathematical Finance Letters. Professor Wirjanto's research fields include functional time series, portfolio optimization, and climate change models and climate change risks.	SJ2 2003
3:30 - 3:45 p.m.	**"Models and Rules for our Global Climate? Advances in Climate Law and Mathematics"** This brief talk, as a collaboration between an established professor of climate law and a young climate activist and mathematician, highlights legal and mathematical innovations that are being developed and piloted in Canada and internationally. It explores the potential of these instruments to enhance synergies and reduce conflicts between climate adaptation and mitigation, and to promote mitigation and adaptation co-benefits, as part of the global response to climate change. With case studies of new international and domestic instruments in climate finance and carbon pricing (including climate risk disclosure), clean energy technologies (including fusion power) and of 'nature based solutions' to climate change, including carbon sequestration, the talk identifies emerging opportunities for current and future generations of research (and decision-making) at the intersection of these crucial fields. **Jona David C. Gehring**, Scholar, Winchester College UK, Co-chair of the Global Youth Council on Science, Law and Sustainability	SJ2 2003

	Jona is a young mathematician and physicist, youth advisor to the board of Energy for the Common Good, ITER researcher and Perimeter Institute ISSYP alumni, author of four UNESCO VoFG children's books on science, co-founder of the Cambridge Schools Eco-Council, British Maths and Physics Olympiad laureate and a climate striker. **Marie-Claire Cordonier Segger**, Visiting Chair in Sustainable Development Law and Policy, University of Cambridge and Professor of Law, University of Victoria Professor Marie-Claire Cordonier Segger FRSC FRSA WIJA is Visiting Chair in Sustainable Development Law and Policy at the University of Cambridge, adjunct professor of the University of Waterloo School of Environment, Enterprise and Development, full professor of law of the University of Victoria, and Senior Director of the Centre for International Sustainable Development Law. As BSIA fellow and Waterloo Climate Institute advisor, executive secretary of the UNFCCC CoP28 Climate Law and Governance Initiative, and senior advisor of the Hughes Hall Centre for Climate Change Engagement and the Cambridge Zero Policy Forum at the University of Cambridge, also founding fellow of the Centre for Energy, Environment and Natural Resources Governance (CEENRG), she has published over 24 books and 160 papers in five languages, and served as senior legal advisor to the UNFCCC Presidency.	
3:45 - 4:00 p.m.	**"Shifting Perceptions on Climate Action: An International Sentiment Analysis of News Media"** Climate change and low-carbon transitions have entered mainstream media discourse. Over the last decade, discussions on decarbonization and net-zero transitions have gained prominence among academics, regulators, practitioners, and the general public. However, these topics also generate more polarization and conflict among actors, which hinders effective climate action. Existing literature on the topic is dated and does not capture the global shift toward conservatism and populism. News media also tends to focus on costs of climate policy so it's unclear if economic benefits or economic implications are discussed. This study conducts a sentiment analysis of social and news media through a deductive analysis of keywords relating to decarbonization and net-zero as solutions for climate action: We consider how these discussions pertain to financial actors, policymakers, and industry. Using sentiment analysis, this study finds that sentiment and discourse differs by stakeholder, over time, and across frames of decoupling and degrowth. We thus highlight how perceptions of these topics have changed over the past 10 years, since the Paris agreement, through the Covid-19 Pandemic and to the current political climate. **Truzaar Dordi**, Postdoctoral Fellow, University of Victoria Truzaar Dordi is an award-winning researcher and post-doctoral fellow at the University of Victoria, working in the fields of climate finance, energy policy, and sustainability transitions. Truzaar holds a Doctorate in Sustainability Management from the University of Waterloo, where he examined the role of capital markets in low carbon transitions. Truzaar currently serves as the Vice President for the Canadian Society for Ecological Economics and served as a member and author for the University of Waterloo's Responsible Investing Advisory Group. He is recognized as a "30 Under 30 Sustainability Leader" and "Clean50 Emerging Leader", awarded for his work on financial stability.	SJ2 2003

4:00 - 4:30	30 Minute small group question harvesting	SJ2 2003
3:15 - 4:30 p.m.	(Round 2) 15 Minute talks – "**Carbon Sequestration**"	SJ2 2007
3:15 - 3:30 p.m.	**"Climate Change and the Primary Sectors: The Role of Carbon in Agriculture and Forestry"** Objective: Based on my research, I have essentially come to the following conclusions: 1. Countries are less interested in preventing climate change, but are interested in virtue signaling—"we have done our part, now do yours" 2. Terrestrial carbon fluxes should not be considered in the accounting of emission-reduction targets (a) Food production is too important (b) Carbon offsets from terrestrial sinks opens the door to corruption (c) Measurement of carbon offsets from activities that prevent GHG emissions are particularly problematic **Cornelis Van Kooten**, Professor (Economics), University of Victoria G. Cornelis van Kooten is professor and Senior Canada Research Chair at the University of Victoria, Canada. He received a Ph.D. in agricultural and resource economics from Oregon State University in 1982. Subsequently he has been an assistant and associate professor in the Department of Agricultural Economics at the University of Saskatchewan; an associate professor in the School of Management at Groningen University in the Netherlands; an associate and full professor in the Departments of Agricultural Economics and Forest Resources Management, and Chair of Agricultural Economics, at the University of British Columbia; and a professor and Chair of the Department of Applied Economics and Statistics at the University of Nevada. Currently, he is a professor in the Department of Economics, and the Canada Research Chair in Environmental Studies and Climate, at the University of Victoria. He is a frequent visiting professor at Wageningen University in the Netherlands, and has been a visiting professor at Washington State University, the VU University in Amsterdam, and the University of Tilburg in the Netherlands. He was previously a senior research fellow at Wageningen Economic Research in The Hague, Netherlands. Dr. van Kooten has over 30 years of experience with interests that range from agricultural and forest economics to development, computational and energy economics. He has published more than 200 peer-reviewed journal articles and some 40 book chapters; he is the author or co-author of five books on land and forest economics, and co-editor of three books. His book with Erwin H. Bulte entitled The Economics of Nature (Blackwell, 2000) is considered a classic reference book for researchers in the field of wildlife and public land economics. And his 1995 paper in the American Journal of Agricultural Economics on the uptake of carbon in forest ecosystems is the standard reference for work in the field of terrestrial carbon offsets. Dr. van Kooten has been a consultant to various governments and government agencies, the United Nations, the World Bank, the European Union, and a variety of non-governmental organizations, including the International Fund for Animal Welfare and the WWF. His numerous graduate students have gone on to work in the private sector, academia and government. He is a Fellow of the Canadian Agricultural Economics Society (2012) and was awarded its Publication of Enduring Quality Award in 2011; in 2014, he won the Faculty of Social Sciences' Research Excellence Award.	SJ2 2007

3:30 - 3:45 p.m.	**"Geological Sequestration of CO_2 (research and challenges)"** Fossil fuels, the largest contributor of human-made carbon dioxide (CO_2) emissions, will continue to be a main source of the global energy supply for the near future. Assessments reported by the Intergovernmental Panel on Climate Change conclude that underground sequestration of CO_2 could play a significant role in mitigating global warming. Industrial scale sequestration projects provide strong empirical support for the view that CO_2 storage can be implemented safely. Nevertheless, significant uncertainties remain regarding the security of underground storage at the scales necessary for this technology to play a significant role in managing global emissions. A few key challenges will be discussed in this presentation: pressure management at high injection volumes; and the risks of leakage. Since CO_2 injected into underground formations (aquifers, or depleted oil and gas reservoirs) is typically less dense than the resident fluids, it could potentially flow upwards, leaking through any high permeability zones or artificial penetrations such as abandoned wells. Lessons learned on the way from academic research to industrial scales implementation will be discussed as well. **Yuri Leonenko**, Associate Professor (Geological Engineering), University of Waterloo Yuri Leonenko holds a joint appointment in the Department of Earth and Environmental Sciences (Faculty of Science) and the Geography and Environmental Management (Faculty of Environment). His main research interest is development of technologies to mitigate global warming. Yuri has been actively involved in practical development and promotion of carbon capture and storage (CCS) technologies participating in such projects as: Shell Sequestration Project (Phase-I, preliminary research). This research led to the commercial (> $1 billion in total) development of Shell's Quest CCS Project. He also played a significant role in development and establishment of Carbon Management Canada (Center of Excellence) with 50 million of government funding. Currently involved in two big NSERC Alliance projects: CO_2 capture and storage assessment for Stelco's Lake Erie facility (Co-PI); and Carbon Capture by Boreal Afforestation: feasibility for Canada's net-zero emission goals (PI)	SJ2 2007

3:45 - 4:00 p.m.	**Learning Persistent Environmental Monitoring Using Multi-Robot Teams** In this talk I will present a learning and control framework to enable multi-robot teams to monitor an environmental field of interest over long time horizons. The approach is based on a control-theoretic measure of the information collected by the robots, which is leveraged in order to learn a distributed multi-robot control policy using the reinforcement learning paradigm. The learned policy is then combined with energy constraints using a constraint-driven control framework in order to achieve persistent environmental monitoring. The proposed approach is showcased in a multi-robot persistent environmental monitoring scenario where a team of robots with limited availability of energy is to be controlled in a coordinated fashion in order to estimate the concentration of a diffusing substance in the environment. **Gennaro Notomista**, Assistant Professor (Electrical and Computer Engineering), University of Waterloo Gennaro Notomista is an Assistant Professor and the Varma Family Professor in Robotics in the Department of Electrical and Computer Engineering at the University of Waterloo (Waterloo, ON, Canada). Prior to joining University of Waterloo, he was a post-doctoral researcher at the CNRS/Inria/IRISA, Rennes, France. He received the Ph.D. degree in robotics from the Georgia Institute of Technology (Atlanta, GA, USA) in 2020. Dr. Notomista is a Fulbright Scholar and was the recipient of the Alumni Small Grant (2020) and the IEEE ARSO Best Paper Award (2022). His main research interests lie at the intersection of design and control of robotic systems for long-duration autonomy with applications to environmental monitoring.	SJ2 2007
4:00 - 4:30	30 Minute small group question harvesting	SJ2 2007
4:30 - 4:45 p.m.	Break (15 minutes)	
4:45 - 5:00 p.m.	Select breakout rooms for grant development groups	SJ2 1002
6:00 - 8:00 p.m.	Dinner Federation Hall is located on the main University of Waterloo campus, approximately a 10 minute walk from St. Jerome's. Parking lot M is the closest visitor parking lot.	Federation Hall

DAY FOUR

Day 4 envisions three topic moderators to lead planning on three research topics (identified during days 1-3), with target grant proposal development in mind.

Time	Event	Room
8:00 a.m.	Breakfast	Atrium

8:50 a.m.	Welcoming Remarks **Deirdre Haskell**, Deputy Director, Fields Institute	
9:00 - 10:20 a.m.	*Research Planning Workshops*	SJ2 1002, 2001 & 2002
10:20 - 10:40 a.m.	Break (20 minutes)	Atrium
10:40 a.m. - 12 p.m.	*Research Planning Workshops (rotate rooms)*	SJ2 1002, 2001 & 2002
12 - 1:30 p.m.	Closing remarks & Lunch	SJ2 Café
1:30 - 3:30 p.m.	MfCC Steering Committee Meeting (*TBC*)	SJ2 2001