香港中文大學
The Chinese University of Hong Kong

香港中文大學理學院
FACULTY OF SCIENCE
THE CHINESE UNIVERSITY OF HONG KONG

2023-24
SCIENCE FACULTY
POSTGRADUATE
RESEARCH DAY

8 MAY 2024

Science *Empowers* Your Dreams

Learn Science to *Better* the World

PROGRAMME

09:30 - 09:45	**Opening Remarks & Souvenir Presentation** ***Professor SONG Chunshan,*** Dean of Science
09:45 - 10:00	**Molecular Mechanisms of Peroxisome Tubulation and Lipid Droplets Degradation in Germinating *Arabidopsis* Seedlings** ***KWOK Ching Yiu Dorcas*** (Year 1 PhD Student in Cell & Molecular Biology)
10:00 - 10:15	**The Possible Roles of a Plant Ribosome-Associated Protein, AtYchF1, on Translational Regulation in *Arabidopsis*** ***CHENG Sau Shan*** (Year 6 PhD Student in Molecular Biotechnology)
10:15 - 10:30	**Synthesis, Structure, and Reactivity of New Masked Anionic Boryl Reagents** ***MAO Xiaofeng*** (Year 4 PhD Student in Chemistry)
10:30 - 10:45	**Density-Equalizing Quasi-Conformal Mapping with Applications** ***LYU Zhiyuan*** (Year 3 PhD Student in Mathematics)
10:45 - 11:00	**Break (15 minutes)**
11:00 - 11:15	**Condensation Completion and Defects in 2+1D Topological Orders** ***YUE Gen*** (Year 2 PhD Student in Physics)
11:15 - 11:30	**Weather Risk Management and Pricing with Spatio-Temporal Random Fields** ***WANG Zexian*** (Year 2 MPhil Student in Risk Management Science)
11:30 - 11:45	**Joint Mixed Membership Modelling of Multivariate Longitudinal and Survival Data for Learning the Individualized Disease Progression** ***HE Yuyang*** (Year 3 PhD Student in Statistics)
11:45 - 12:00	**Impacts of Surface Ozone Pollution on Agriculture in China: Application of Innovative Technologies, Social Outcomes, and Policy Implications** ***MAO Jia*** (Year 3 PhD Student in Earth & Atmospheric Sciences)
14:30 - 16:30	**Poster Presentation at LSK LT4 Foyer** ***(Tea Refreshment: 14:30 - 16:00)***

Welcome Message from the Dean of Science

Professor Chunshan SONG

It is with great pleasure that I welcome you all to the 2024 Science Faculty Postgraduate Research Day. We have organised Faculty Postgraduate Research Day every year since 2021. Scientific research is an important part of postgraduate education for cultivating creative minds at a leading research university. The annual Science Faculty Postgraduate Research Day serves as a platform for our postgraduate students to showcase their original research work, exchange ideas, learn from each other and foster communication and collaboration within the science community.

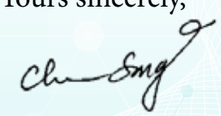
This year holds special significance as we commemorate the 60th anniversary of the CUHK Science Faculty - a momentous occasion to celebrate a rich legacy of academic excellence, research breakthroughs, and contributions to society. Over the past six decades, our Science Faculty has remained steadfast in its commitment to nurturing future leaders and creative professionals and driving scientific innovation. As we reflect on our history, we find inspiration in the profound impact that our faculty members, researchers, and postgraduate students have made in advancing knowledge, addressing societal challenges, and fostering sustainable development.

At CUHK, we are dedicated to providing a nurturing environment that empowers our postgraduate students to excel in their research pursuits to embody the Faculty motto of "*Science empowers your dream. Learn Science to Better the World*". Through close collaboration with our esteemed faculty members and access to state-of-the-art facilities, our students receive comprehensive training and guidance to become the next generation of scientific leaders. We also value the development of transferable skills alongside disciplinary expertise. Critical thinking, effective communication, collaboration, and leadership are integral to becoming well-rounded researchers who can make meaningful contributions to society and create a positive impact on the world.

I would like to express my heartfelt appreciation to the event coordinator Professor To NGAI, all presenters, all graduate division heads, participants, faculty members, and staff who have contributed in various ways to this Postgraduate Research Day. This is also a great opportunity for us to learn and to celebrate the achievements of our postgraduate researchers.

I wish you all a fruitful day on the 2024 Postgraduate Research Day. Thank you.

Yours sincerely,



Chunshan SONG
Dean of Science and
Wei Lun Professor of Chemistry

Oral Presentation

Abstract

Molecular Mechanisms of Peroxisome Tubulation and Lipid Droplets Degradation in Germinating *Arabidopsis* Seedlings

KWOK Ching Yiu Dorcas
Year 1 PhD Student in Cell and Molecular Biology
Principal Supervisor: Professor JIANG Liwen

During seeding development, lipid droplets (LDs) are accumulated, and serve as an essential energy reserve to support seedling germination. **Peroxisome** is a membrane-bound organelle, which is majorly responsible for lipolysis, one of the major pathways involve in LD degradation. During lipolysis, LDs are engulfed by tubular peroxisome and degraded by the peroxisome-localized lipase SUGAR DEPENDENT 1 (**SDP1**). In addition, the formation of peroxisome is driven by peroxisomal biogenesis factor peroxin (**PEX**) 11s.

We have recently characterized a plant-unique endosomal sorting complex required for transport (ESCRT) component termed FYVE domain protein required for endosomal sorting 1 (**FREE1**). We demonstrated that FREE1 plays an essential role in lipolysis in germinating Arabidopsis seedlings, in which FREE1 acts as a scaffold to link SDP1 and PEX11e together during lipolysis in peroxisome. In addition, FREE1 is essential for peroxisome tubulation and proper targeting of SDP1 to peroxisome. However, the underlying mechanisms remain elusive.

In this study we aim to elucidate the molecular mechanisms of FREE1-mediated peroxisome tubulation in Arabidopsis with two major objectives: 1) To study the dynamic formation of peroxisome tubulation in transgenic plant cells as visualized by SDP1 and/or PEX11e dynamics via live-cell imaging analysis; and 2) To identify putative FREE1- and/or PEX11e- interacting proteins by in vitro pull down assay, and subsequent MS/MS analysis for protein identification, followed by functional analysis on selected protein candidates in transgenic plants and knockdown/knockout mutants.

Our preliminary confocal imaging analysis on transgenic plants expressing XFP-fusion with SDP1 or PEX11e showed that peroxisomes exhibit highly active dynamics including tubules elongation, navigation, connection and network formation. In addition, the dynamics of peroxisome tubulation are cell-type specific, developmentally regulated and sucrose-dependent. Without sucrose supplement, both SDP1- or PEX11e-marked peroxisomal tubules show more rapid dynamics, suggesting that sucrose may play a role in mediating LD degradation/homeostasis. On-going studies will be focus on investigating the relationship between sucrose depletion and peroxisome-mediated LD degradation.

This study will provide new insights about the mechanisms of peroxisome tubulation and LD degradation in plants. By understanding the mechanism of peroxisome-mediated LD turnover, we hope that in long term, the germinating rate of seedlings can be increased, and thus enhance the crop yield. This work submitted by Dorcas has recently been selected for an oral presentation for the upcoming 13th International Congress on Plant Molecular Biology (IPMB) to be held in June 24-28, 2024 in Cairns, Australia.

Keywords: FREE1, Lipid Droplet Degradation, Peroxisome, PEX11e, SDP1

The Possible Roles of a Plant Ribosome-Associated Protein, AtYchF1, on Translational Regulation in *Arabidopsis*

CHENG Sau Shan
Year 6 PhD Student in Molecular Biotechnology
Principal Supervisor: Professor LAM Hon Ming

Living organisms have evolved mechanisms to regulate gene expression to adapt to their constantly changing environment and overcome unfavorable encounters. Translation, a dynamic biological process for protein synthesis, enables the organism to respond to external stimuli for better survivorship. An unconventional conserved GTPase, YchF, mediates stress tolerance in various organisms such as humans, rice, Arabidopsis thaliana, yeast, and *Escherichia coli*. In plants, previous studies suggested a negative correlation between plant susceptibility to stress and the cellular level of YchF. Despite the high sequence homology and functional similarities observed in YchF members, the detailed mechanisms of how plant YchFs regulate stress responses remain elusive.

YchF proteins structurally resemble members of nucleotide-hydrolyzing proteins from the translation factor (TRAFAC) family that possibly regulate translation. Studies conducted using mammalian and bacterial YchF homologs showed their interaction with the translation machinery components, which could influence the translation of transcripts for stress adaptation. Therefore, it is hypothesized plant YchF homologs might influence translation efficiency and regulate stress adaptation via interacting with the translation machinery components, as its bacteria, yeast, and human homologs do.

In this study, using *Arabidopsis* as a study model, we identified the functional importance of AtYchF1 in interacting with the ribosomal protein AtRPS7. We identified the binding interface between AtYchF1 and AtRPS7 by protein structural analyses and *in vitro* pull-down experiments, providing evidence to support their direct interaction. To decipher the role of AtYchF1 and the significance of its AtRPS7-binding property in translation regulation, we constructed transgenic *Arabidopsis* lines overexpressing *AtYchF1* or *AtY34*, which encodes respectively the native and a mutant form of AtYchF1 incapable of binding AtRPS7, in *AtYchF1*-knockdown mutant as genetic background. These lines are the genetic materials to study the effect of AtRPS7-binding on AtYchF1 function. Our unpublished TMT-labelled proteomic data hinted that, even in unstressed conditions, the AtYchF1 alters the protein profiles in plants in an AtRPS7-binding dependent manner. Reactive oxygen species (ROS) scavengers were down-regulated in the unstressed *AtYchF1*-overexpressor but not the *AtY34*-overexpressor nor the *AtYchF1*-knockdown mutant. As suggested in the polysome profiling coupled RNA-sequencing, overexpression of *AtYchF1* coincident with the reduction of stress-related proteins encoding mRNAs loading into the actively translating polysome, which the ribosomal protein AtRPS7 binding of AtYchF1 plays a critical role. We also identified a consensus CUCU motif enriched in the 3' untranslated regions of the down-regulated stress-related-encoding mRNAs, in which the motif is the specific binding target of AtYchF1, regardless of its AtRPS7 binding capability.

Altogether, these results demonstrated that AtYchF1 contributes to stress response modulation by influencing the translation of mRNAs encoding stress-related proteins in plants. Our study shed light on the functional significance of YchF homolog on stress regulation, and this conserved protein could be one of the candidates for climate-smart crop breeding and improvements.

Acknowledgement: This work was supported by grants from the Hong Kong Research Grants Council: General Research Fund (14164617) and Area of Excellence Scheme (AoE/M-403/16)

Synthesis, Structure, and Reactivity of New Masked Anionic Boryl Reagents

MAO Xiaofeng
Year 4 PhD Student in Chemistry
Principal Supervisor: Professor XIE Zuowei

Carbene has emerged as a significant building block in fundamental organic synthesis, whereas the explorations on the anionic six-electron boron-analogues are relatively exclusive. Typically, six-electron group 13 anions possess both nucleophilicity and basicity, thus allowing for small molecule activation and C-H activation. Currently, most persistent boryl anions rely on stabilizations from two adjacent heteroatoms and rigid skeletons, so-called heterocyclic boryl anions, which significantly restrict the reactivity of boron centers, whereas two-carbon-substituted boryl anions are inherently unstable (**Fig. 1A**). Herein, we developed different diarylboryl anion transfer reagents, and utilized them in boron-centered nucleophilic reactions and C(sp²)-H borylation (**Fig. 1B**).

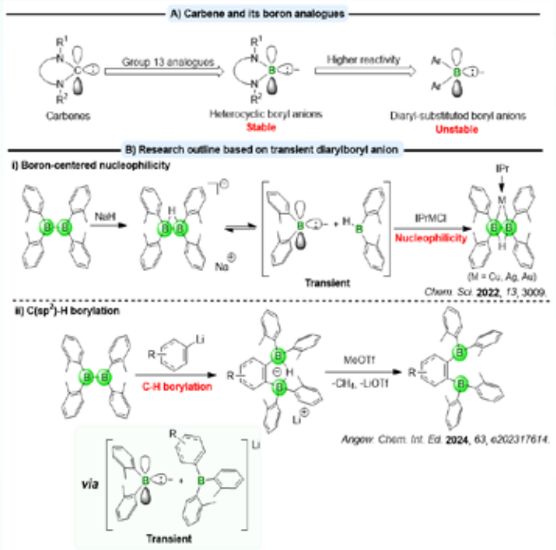


Fig 1. A) Introduction; B) Research outline.

i) Boron-centered nucleophilicity: The sodium (μ-hydrido)diborane(4) was synthesized through the reaction of B_2(*o*-tolyl)$_4$ with NaH, and it shows a σ-B–B bond nucleophilic behavior towards (IPr)MCl (M=Cu, Ag, and Au), to give different η^2-B–B bonded complexes, where the transient diarylboryl anion first reacts with (IPr)MCl to give IPrCuB(*o*-tolyl)$_2$, followed by the interaction with HB(o-tolyl)$_2$ to give η^2-B–B bonded complexes (Mao, X. *et al. Chem. Sci.*, **2022**, *13*, 3009).

ii) C(sp²)-H borylation: The reaction of B_2(*o*-tolyl)$_4$ with aryllithium would give various 1,2-diborylaryl lithium species, where the transient diarylboryl anion activates intramolecular C(sp²)-H bond via nucleophilic aromatic substitution of aryllithium. In addition, neutral species can be obtained by treating these diborylaryl anions with hydride-abstracting reagents (Mao, X. *et al. Angew. Chem. Int. Ed.* **2024**, *63*, e202317614).

Acknowledgement: These works were supported by grants from the Research Grants Council of HKSAR (Project No. 14303621 and 14307421.) and the Southern University of Science and Technology (to Z. X).

Density-Equalizing Quasi-Conformal Mapping with Applications

LYU Zhiyuan
Year 3 PhD Student in Mathematics
Principal Supervisor: Professor LUI Lok Ming Ronald

In our research, we present a set of innovative approaches designed to compute bijective density-equalizing quasi-conformal maps for connected open surfaces and genus-0 closed surfaces. Traditional density-equalizing maps tend to rely solely on predetermined constraints related to the distribution of density, which is defined as the population per unit area. However, these maps often overlook the control of bijectivity and local geometric distortions in the mappings. Furthermore, they primarily focus on simply-connected open surfaces, neglecting surfaces with more intricate topologies.

To address these limitations, our proposed methods combine the density diffusion process with quasi-conformal theory. This integration enables effective control over local geometric distortion while ensuring the bijectivity of the mapping. We achieve this by formulating an energy minimization problem that involves the Beltrami coefficient of the mapping. By doing so, we strike a balance between geometric fidelity and preserving the bijectivity between the original and flattened surfaces.

Furthermore, for surfaces with multiple connected components, we develop an iterative scheme that optimizes both the shape of the target planar circular domain and the density-equalizing quasi-conformal map onto it. This iterative scheme allows us to achieve an optimal parameterization of multiply-connected surfaces, enhancing the overall accuracy and quality of the resulting flattening maps.

Additionally, our proposed methods offer the flexibility to incorporate landmark constraints, which ensure consistent feature alignment across the surfaces. This feature is particularly useful when preserving specific anatomical or structural landmarks is critical.

By manipulating the prescribed population, our techniques allow for the generation of a wide range of surface maps with diverse desired properties. We have extensively tested these methods on synthetic and real-world examples, demonstrating their efficacy in various applications within the realms of computer graphics and medical imaging.

In conclusion, our work introduces novel methods that address the limitations of conventional density-equalizing maps by offering enhanced control over bijectivity, local geometric distortions, and handling surfaces with complex topologies. The integration of density diffusion and quasi-conformal theory, along with the incorporation of landmark constraints, opens up new possibilities for generating high-quality flattening maps that cater to specific needs in diverse fields. Through extensive experimentation, we have demonstrated the efficacy and versatility of our methods, paving the way for advancements in computer graphics and medical imaging research.

Condensation Completion and Defects in 2+1D Topological Orders

YUE Gen
Year 2 PhD Student in Physics
Principal Supervisor: Professor LAN Tian

We review the condensation completion of a modular tensor category, which yields a fusion 2-category of codimension-1 and higher defects in a 2+1D topological order. We apply the condensation completion to 2+1D toric code model, three fermion model and a $\mathbb Z_4$ chiral topological order. In these cases, we explicitly enumerate the 1d and 0d defects present in these topological orders, along with their fusion rules. We also talk about other applications of condensation completion: alternative interpretations of condensation completion of a braided fusion category; condensation completion of the category of symmetry charges and its correspondence to gapped phases with symmetry; for a topological order $\mathcal C$, one can also find all gapped boundaries of the stacking of $\mathcal C$ with its time-reversal conjugate through computing the condensation completion of $\mathcal C$.

Acknowledgement: We are grateful to the helpful discussions with Chenqi Meng and Holiverse Yang. TL is supported by start-up funding from The Chinese University of Hong Kong, and by funding from Research Grants Council, University Grants Committee of Hong Kong (ECS No.~24304722).

Weather Risk Management and Pricing with Spatio-Temporal Random Fields

WANG Zexian
Year 2 MPhil Student in Risk Management Science
Principal Supervisor: Professor SIT Tony

Climate change results in unpredictable weather conditions which can affect various industries. In the US, climate change causes GDP to decrease by 1 to 4 percent annually, economic losses due to extreme weather events exceeded $603.1 billion from 2019 to 2023 and costs due to heat exposure have been increasing rapidly as well. Many groups of people including insurance companies, agricultural producers and corporate and individual investors are concerned with managing weather risk through the capital market and weather derivative securities, such as those traded at the Chicago Mercantile Exchange (CME), are natural investment vehicles for that purpose. Since the payoffs of weather derivatives depend on variables such as the temperatures at specific locations over certain periods of time, we propose a new pricing model for weather derivatives to capture the disentangled temporal and spatial dependence structures of the underlying variables within a unified framework integrating important stylized facts such as non-Gaussianity, leading to more effective management and hedging of weather risk and spatial risk.

Under our new framework, the temporal evolutions of the deseasonalised temperatures are modelled by the unique weak solutions of multivariate Levy-driven stochastic delay differential equations (SDDEs) to incorporate jumps and delay effects, serving as an extension to the stochastic modelling framework via multivariate Levy semistationary (MLSS) processes, which are the null-spatial cases of ambit processes, with investigations on the semimartingale conditions and asymptotic properties of the temporal processes including the convergence of their power variations. These are accompanied with underlying stochastic volatility processes to account for the spatial dependence structures approximated by Matern fields expressed as the solutions arising from SPDEs driven by non-Gaussian noise processes, where efficient estimation is provided through approximate Bayesian inference via integrated nested Laplace approximations (INLA) and variational Bayesian inference via optimal surrogate densities, and the consistency of the coordinate ascent variational inference (CAVI) algorithms used for the latent non-Gaussian models is also established. Analytical pricing formulae are derived under a suitable family of measure changes via the generalised Esscher transform and structure preserving minimal entropy martingale measures (MEMMs).

With the new valuation methods, further analysis is carried out on the volatility term structure of the futures prices by extending functional Ito calculus for non-anticipative functionals to Hilbert space valued stochastic processes. We also investigate optimal portfolios for geographic locations without measurement data and devise effective hedging strategies for spatial risk. Empirical studies are conducted for various background driving Levy processes (BDLPs) which belong to the class of generalised hyperbolic (GH) processes having infinite activity and type G Levy noise processes governing the Matern fields. Numerical examples demonstrate the significant improvements on the accuracy and efficacy of the calibration and computation of the derivatives prices offered by the analytical formulae or the Fourier simulation schemes developed under the multivariate setting, the time-varying implied market price of risk (MPR) and market price of volatility risk, and observations from the volatility term structure such as the modified Samuelson effect.

Joint Mixed Membership Modelling of Multivariate Longitudinal and Survival Data for Learning the Individualized Disease Progression

HE Yuyang
Year 3 PhD Student in Statistics
Principal Supervisor: Professor SONG Xinyuan

Patients with Alzheimer's disease (AD) often exhibit substantial heterogeneity in disease progression due to multiple genetic causes for such a complex disease. Investigating diverse subtypes of neurodegeneration and individualized disease progression is essential for early diagnosis and precision medicine. In this article, we present a novel joint mixed membership model for multivariate longitudinal AD-related biomarkers and time of AD diagnosis. Unlike conventional finite mixture models that assign each subject a single subgroup membership, the proposed model assigns partial membership across subgroups, allowing subjects to lie between two or more subgroups. This flexible structure enables individualized disease progression and facilitates the identification of clinically meaningful neurological statuses often elusive in current mixed effects models. We employ a spline-based trajectory model to characterize complex and possibly nonlinear patterns of multiple longitudinal clinical markers. A Cox model is then used to examine the effects of time-variant risk factors on the hazard of developing AD. We develop a Bayesian method coupled with efficient Markov chain Monte Carlo sampling schemes to perform statistical inference. The proposed approach is assessed through extensive simulation studies and an application to the Alzheimer's Disease Neuroimaging Initiative study, showing a better performance in AD diagnosis than existing joint models.

Keywords: Mixed membership model; Longitudinal data; MCMC methods; Survival data

Impacts of Surface Ozone Pollution on Agriculture in China: Application of Innovative Technologies, Social Outcomes, and Policy Implications

MAO Jia
Year 3 PhD Student in Earth and Atmospheric Sciences
Principal Supervisor: Professor TAI Pui Kuen Amos

By applying a hybrid approach combining chemical transport model and machine learning, we investigate multidecadal ozone trends in China and implications for crop yields. The estimated relative yield losses (RYLs) for wheat, rice, soybean and maize are 17.6%, 13.8%, 11.3% and 7.3% in 1981, and increased to 24.2%, 17.5%, 16.3% and 9.8% in 2019, with an increasing rate of +0.03% yr^{-1}, +0.04% yr^{-1}, +0.27% yr^{-1} and +0.13% yr^{-1}, respectively. Present-day ozone pollution has led to national crop production losses (CPLs) of 116.4 Mt for grain crops, equivalent to economic losses (ELs) of 63.4 billion USD. These losses are unevenly distributed among the 31 provinces with a Gini index of 0.57, wherein most of the grain-producing provinces, the primary cost bearers (e.g., Henan and Shandong), have a per capita disposable income below the median. Moreover, within the grain-producing provinces, economic growth from high-emission activities in grain-producing provinces fails to sufficiently benefit the true bearers—farmers. For every unit increase in the per capita GDP of secondary and tertiary industries, urban residents' per capita disposable income rises by 0.41–1.17 CNY, and rural residents' by 0.19–0.58 CNY. In different emission reduction scenarios, due to the seasonal shift of ozone formation regimes, the wheat growers over the North China Plain may counterproductively greater CPLs if mitigation of volatile organic compounds (VOCs) is neglected. Developing effective region-specific emission control is therefore critical to improve air quality, safeguard food safety, and promoting social justice toward a more sustainable development. Additionally, external aid (e.g., economic subsidies) should be provided to help farmers improve livelihood and escape "poverty trap" as they bear a disproportionate share of the negative environmental impacts of pollution.

Poster Presentation

Abstract

Poster No.	Graduate Division	Presenter	Presentation Title
SLS-01	Life Sciences	BASS Alissa Victoria	**Marine Heatwaves and Light Limitation Independently Alter the Growth, Productivity and Leaf Microbiome of a Tropical Seagrass**
SLS-02	Life Sciences	LI Yuxuan	**Truncated and Cyclized SUMO1 Inhibits Aβ Aggregation and Toxicity through Stabilization of Aβ Monomers**
SLS-03	Life Sciences	LUI Ying Lam	**Molecular Mechanism of Ataxia Diseases: Dysregulation of YY1-Wnt10b-PKCγ Signaling Axis in Cerebellar Purkinje Cell Development**
SLS-04	Life Sciences	YEUNG Hoi Wa	**The Role of Adipocyte PD-L1 Signaling in Modulating Metabolic Plasticity for the Prevention of Obesity**
CHM-01	Chemistry	GE Fangyuan	**Improved Sunscreen Formulations Utilizing Cinnamate-Functionalized Hollow Microspheres for Enhanced UV Protection**
CHM-02	Chemistry	LOU Xiangyu	**Stereoselective Unsymmetrical 1,1-Diborylation of Alkynes with a Neutral sp^2 - sp^3 Diboron Reagent**
PMA-01	Mathematics	HU Tianhao	**Solving Elliptic Problems with Singularities Using Splitting Technique and Deep Learning Methods**
PMA-02	Mathematics	LI Yan Lung	**Equivariant Lagrangian Correspondence and a Conjecture of Teleman**
PHY-01	Physics	CHAN Lik Chun	**Different Dynamical States of Spontaneous Activity of Neurons in a Network**
PHY-02	Physics	XIA Xinyue	**Modulation of Two-Dimensional Exciton Emissions by (Gold Nanodisk)-on-Mirror Cavities**
RMS-01	Risk Management Science	CHENG Pok Him	**Test for Network Independence with Distance Correlation**
RMS-02	Risk Management Science	MA Ting Tin	**Optimally Jittered Inference of Jump for High-Frequency Data**
STA-01	Statistics	LI Chenghao	**A Nonparametric Contrastive Learning Approach to Density Estimation**
STA-02	Statistics	LI Dongrong	**Large Scale Bayesian Computation with Stochastic Gradient Barker Jump**
EAS-01	Earth & Atmospheric Sciences	LAU Chung Shing	**Investigating Climate Change and Urbanization Impacts on Summer Thermal Environment in Greater Bay Area of China**
EAS-02	Earth & Atmospheric Sciences	ZHANG Wensong	**Revealing Surface Water System on the Greenland Ice Sheet Using Artificial Intelligence**

Marine Heatwaves and Light Limitation Independently Alter the Growth, Productivity and Leaf Microbiome of a Tropical Seagrass

BASS Alissa Victoria
Year 3 PhD Student in Environmental Science
Principal Supervisor: Professor THIBODEAU Benoit

Seagrasses are important marine foundation species, which support high coastal biodiversity and provide many socioeconomic benefits. However, seagrasses are threatened by anthropogenic change, both climate and non-climate related, for example, marine heatwaves (MHWs) and concurrent light limitation from eutrophication or increased sediment load can potentially interact to affect seagrass growth, nitrogen cycling, and the microbiome. In this experiment, we exposed the tropical seagrass Halophila ovalis to a 10-day MHW and three light intensities to examine the impacts of these two stressors on the growth, productivity, nitrogen cycling, and leaf microbiome of the seagrass. We found that both MHW and decreased light negatively impacted aspects of seagrass growth of new leaves, with decreased light also reducing new leaf area and rhizome elongation rate and the occurrence of MHWs increasing the rate of leaf loss. Similarly, chlorophyll concentration was altered by both stressors independently, with the common adaptational responses to reduced light (increasing chlorophyll concentration) being significantly lower under the MHW treatment. Nitrogen assimilation rate into the leaves also decreased under both MHW temperature and reduced light availability. The leaf microbiome shifted between the temperature treatments, towards relatively more anaerobic microbes but less oxidative stress-tolerant bacteria, as well as less prokaryotes performing phototrophy and (oxygenic) photoautotrophy with increase temperature and diminished light availability. We found no interactive effects of MHW and light limitation on Halophila ovalis. In conclusion, we show that MHWs as well as light limitation can drive decreased productivity of seagrass and cause shifts in the leaf microbial functional groups. It is therefore important that good water clarity and habitat health is maintained in order to reduce the susceptibility of seagrasses to extreme climatic events.

Truncated and Cyclized SUMO1 Inhibits Aβ Aggregation and Toxicity through Stabilization of Aβ Monomers

LI Yuxuan
Year 4 PhD Student in Biochemistry
Principal Supervisor: Professor CHAN Michael Kenneth

The self-assembly of Amyloid β(Aβ) is believed to be both the initiator and hallmark of Alzheimer's Disease (AD). In particular, the soluble Aβ oligomers (AβOs) are highly neurotoxic and are the prime targets of elimination in AD treatment. Here, we developed and characterized a truncated SUMO1 protein, SUMO1(15-92), capable of binding and stabilizing monomeric Aβ in its native state. The biochemical analyses demonstrated that the SUMO1(15-92) protein interacted with full-length Aβ peptide and prevented the intrinsically disordered Aβ from structural transition. Both primary and secondary nucleation of Aβ peptide were hampered in the presence of SUMO1(15-92) in Aβ aggregation assay. Determination on binding affinity between Aβ peptide fragments and SUMO1(15-92) revealed that the highly hydrophobic C terminus of Aβ, which contains 2 putative SIM sites are critical for SUMO1(15-92) interaction. When expressed in cellular AD model, SUMO1(15-92) significantly reduced the cell-derived AβOs. Inspired by the pyrrolysine incorporation system, we engineered a cyclic version of SUMO1(15-92) and observed a remarkable improvement on its stability *in vitro*. Moreover, the cyclic SUMO1(15-92) was capable of rescuing Aβ transgenic Caenorhabditis elegans model from Aβ-associated toxicity.

Molecular Mechanism of Ataxia Diseases: Dysregulation of YY1-Wnt10b-PKCγ Signaling Axis in Cerebellar Purkinje Cell Development

LUI Ying Lam
Year 4 PhD Student in Cell and Molecular Biology
Principal Supervisor: Professor KWAN Kin Ming

The cerebellum coordinates motor and non-motor functions. As the signal integration center in the cerebellum, Purkinje cells (PCs) receive various signals through their extensive dendritic tree and transmit an output signal to the cerebellar and vestibular nuclei. Impaired dendritogenesis and synaptogenesis in PCs can cause chaotic outcomes in cerebellar circuitry, leading to behavioral disorders associated with neurological impairment.

Yin Yang 1 (YY1) is a ubiquitously expressed zinc-finger-like transcription factor that plays diverse roles in development. In humans, Gabriele-de Vries syndrome, caused by *Yy1* mutation with deletion or missense, is characterized by developmental delay and a wide range of morphological abnormalities. Half of individuals with this syndrome experience neurological manifestations, including gait abnormalities and hypotonia. However, the cellular and molecular mechanisms underlying these pathological manifestations are unknown. Therefore, to better understand the pathological mechanisms of motor coordination in YY1 syndrome, we aimed to investigate the developmental mechanisms regulated by YY1 in Purkinje cells.

In this study, we demonstrate that genetic abolishment of *Yy1* in PCs postnatally resulted in a cerebellar ataxia phenotype accompanied by progressive cerebellar atrophy. Interestingly, we observed significantly defective PC dendritogenesis in mutant mice, which led to weakened synaptic plasticity and dysregulation of Protein kinase C gamma (PKCγ). Through transcriptomic analysis of ataxic-like mutants, we found that Wnt10b, a specific activator of the Wnt/β-catenin pathway that is exclusively and transiently expressed in postnatal PCs, exhibited downregulation. We show that Wnt10b expression is transcriptionally activated by YY1. Functional studies of Wnt10b using siRNA and recombinant Wnt10b delivery ex vivo indicated that Wnt10b plays a positive role in postnatal PC dendritogenesis and PKCγ activation.

Our study suggests that YY1 regulates Wnt10b expression to control PC dendritogenesis, which in turn mediates PKCγ activation. Furthermore, the novel pathway YY1-Wnt10b-PKCγ that we propose may provide insights into the potential roles of Yy1 in PC development and offer additional molecular clues regarding YY1 haploinsufficiency and PKCγ-associated spinocerebellar ataxia.

The Role of Adipocyte PD-L1 Signaling in Modulating Metabolic Plasticity for the Prevention of Obesity

YEUNG Hoi Wa
Year 2 PhD Student in Cell and Molecular Biology
Principal Supervisor: Professor WONG Wing Tak Jack

Background: Obesity and its related complications have been markedly raised in recent decades, alarming the continuous increase in disease and healthcare financial burden. Pathological remodeling of white adipose tissue (WAT) is responsible for the worsened metabolic status in obesity, which shows features such as disrupted lipid metabolism and adipokines secretion, adipocyte hypertrophy, leukocytes infiltration. The conversion of white adipocytes into brown-like adipocytes, browning, is considered a way to tackle obesity due to its energy-consuming property. Programmed cell death ligand 1 (PD-L1) is a target of immunotherapy, however, exacerbated metabolic health is observed in patients receiving the PD-L1 monoclonal antibody treatment. Notably, PD-L1 is expressed on adipocytes and serves as a brown adipose tissues (BATs) marker. Though the immunoregulating role of PD-L1 is well studied, little is known about its intrinsic metabolic role in adipocyte.

Hypothesis: The preliminary findings suggest that the lack of functional PD-L1/PD-1 signaling in adipocyte aggravated the metabolic health during obesity. The activation of PD-L1 signaling suppressed lipogenesis and stimulated lipolysis, fatty acid oxidation and glycolysis. In addition, PD- L1/PD-1 axis is also involved in adipocyte browning. In line with these findings, increase in adipocyte PD-L1 expression in obesity may favor the restoration of adipocyte functionality. Based on these findings, our group hypothesize that adipocyte PD-L1 may ameliorate obesity and improve metabolic health through regulating the metabolic reprogramming in adipocyte and adipose tissues (ATs) homeostasis, which is independent of immunogenic responses.

Significance: These data suggest the functional importance of adipocyte PD-L1 expression in maintaining ATs homeostasis intrinsically for the first time. This study will provide a new mechanistic explanation for why the dysfunctional PD-L1 axis contributes to metabolic unhealthiness and failure in browning. Comprehensive picturing of the adipocyte PD-L1 network will offer therapeutic targets for treating obesity.

Improved Sunscreen Formulations Utilizing Cinnamate-Functionalized Hollow Microspheres for Enhanced UV Protection

GE Fangyuan
Year 2 PhD Student in Chemistry
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Solar radiation is vital for various aspects of life on Earth, but excessive exposure to ultraviolet (UV) radiation poses significant health risks. To mitigate the harmful effects of UV radiation, sunscreen plays a crucial role in sun protection strategies. Sunscreen agents are broadly categorized into inorganic and organic UV filters. However, concerns have been raised regarding to the use of organic UV filters in cosmetic products, including issues related to poor photostability and the formation of dangerous radicals. Inorganic UV filters have gained popularity in the sun care market, but they often leave a white mark on the skin, which remains an unresolved problem.

To address these challenges, we present a novel method for preparing of hollow microspheres using Cinnamate-functionalized cellulose nanocrystals (Cin-CNCs) and inorganic nanoparticles (SiO_2 or TiO_2) through the Pickering emulsion template to improve the efficacy and the safety of sunscreens. We first investigated the stabilization mechanism of emulsion stabilized using SiO_2 or TiO_2 as particulate stabilizers. Our findings reveal that the hydrolysis products of tetraethyl orthosilicate (TEOS), Cin-CNCs and SiO_2 nanoparticles work synergistically to stabilize the emulsion droplet during the preparation process. The resulting Cinnamate-functionalized hollow microspheres exhibit excellent water dispersibility and superior photostability compared to conventional organic UV filters. In contrast to inorganic UV filters, these hollow microspheres demonstrate higher transparency and enhanced UV shielding properties due to the grafting of cinnamate groups and their hollow structure. Moreover, when incorporated into sunscreen formulation, the cinnamate-functionalized hollow microspheres provide higher Sun Protection Factor (SPF) values compared to conventional inorganic UV filters.

Therefore, we anticipate that these novel hollow microspheres are be effectively incorporated into cosmetic formulations, offering improved UV protection and addressing the limitations associated with existing sunscreen products.

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Stereoselective Unsymmetrical 1,1-Diborylation of Alkynes with a Neutral sp^2 - sp^3 Diboron Reagent

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The incorporation of boron into organic molecules has received growing research focus. Given the versatility of the carbon-boron bond, borylated compounds can readily undergo derivatization, enabling the facile introduction of various functional groups. 1,1-Diborylalkene is a class of diboryl species. It can serve as a precursor of multisubstituted olefins, which are prevalent building blocks in natural products and drug molecules. Here we report a method to access unsymmetrical 1,1- diborylalkene (UDBA) stereoselectively via the reaction of readily available alkynes with a neutral sp^2-sp^3 diboron reagent. Attributing to the chemically easily distinguishable nature of the sp^2 and sp^3 boryl moieties, controllable stepwise derivatization of the resultant UDBAs is realized. This process leads to various multifunctionalized olefins and organoborons, such as acylboranes, which are difficult to prepare by other methods [1].

Keywords: Acryborane, Boron, gem-Diborylation, Stereoselective, Unsymmetrical Diborane

References:

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Solving Elliptic Problems with Singularities Using Splitting Technique and Deep Learning Methods

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In this work, we develop an efficient solver based on neural networks for second-order elliptic equations with variable coefficients and singular sources. This class of problems covers general point sources, line sources and the combination of point-line sources, and has a broad range of practical applications. The proposed approach is based on decomposing the true solution into a singular part that is known analytically using the fundamental solution of the Laplace equation and a regular part that satisfies a suitable modified elliptic PDE with a smoother source, and then solving for the regular part using the deep Ritz method. A path-following strategy is suggested to select the penalty parameter for enforcing the Dirichlet boundary condition. Extensive numerical experiments in two- and multi-dimensional spaces with point sources, line sources or their combinations are presented to illustrate the efficiency of the proposed approach, and a comparative study with several existing approaches based on neural networks is also given, which shows clearly its competitiveness for the specific class of problems. In addition, we briefly discuss the error analysis of the approach.

Physics-Informed Neural Networks (PINNs) are a powerful class of numerical solvers for partial differential equations, employing deep neural networks with successful applications across a diverse set of problems. However, their effectiveness is somewhat diminished when addressing issues involving singularities, such as point sources or geometric irregularities, where the approximations they provide often suffer from reduced accuracy due to the limited regularity of the exact solution. In this work, we investigate PINNs for solving Poisson equations in polygonal domains with geometric singularities and mixed boundary conditions. We propose a novel singularity enriched PINN (SEPINN), by explicitly incorporating the singularity behavior of the analytic solution, e.g., corner singularity, mixed boundary condition and edge singularities, into the ansatz space, and present a convergence analysis of the scheme. We present extensive numerical simulations in two and three-dimensions to illustrate the efficiency of the method, and also a comparative study with several existing neural network based approaches.

Equivariant Lagrangian Correspondence and a Conjecture of Teleman

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We study the Lagrangian Floer theory of G-equivariant Lagrangian correspondences. We apply it to derive relations between the disc potential of an invariant Lagrangian submanifold and that of its quotient, which resolves (a Floer-theoretic version of) a conjecture of Teleman on 2d mirror constructions of symplectic quotients from those of Hamiltonian G-spaces.

Different Dynamical States of Spontaneous Activity of Neurons in a Network

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Principal Supervisor: Professor CHING Shuk Chi Emily

Cortical neurons fire even in the absence of sensory inputs. Experimental measurements have demonstrated that such spontaneous activity is correlated spatially and temporally, forming neuronal avalanches with power-law distributed sizes and time durations, and can influence the neuronal responses under external stimuli. As of today, the mechanism and functional significance of spontaneous activity remain poorly understood. In this work, we study numerically the dynamics of a network of neurons subjected to a stochastic current, using biologically plausible models of neurons with adaptation and conductance-based synapses.

By mapping out the possible dynamics in a broad regime of the parameter space of excitatory and inhibitory synaptic strengths, we find three distinct dynamical states: (I) independent and irregular spiking, (II) coherent bursting, and (III) incoherent bursting. For a given inhibitory synaptic strength, the dynamics changes from state I to II and finally to III as the excitatory synaptic strength is increased. The values of excitatory synaptic strength at which transitions happen depend only weakly on the inhibitory synaptic strength. In state I, the neurons are effectively uncoupled and each neuron fires nearly independently, triggered by the noise. We show that such a state of independent and irregular spiking becomes unstable when excitatory coupling is sufficiently large. As a result, the dynamics undergoes a transition to state II in which each neuron fires in bursts and the bursting dynamics of the neurons are coherent such that the time-binned firing rate of the whole network at a time scale of about 50 ms is oscillatory. At smaller time scales, the bursting activity forms neuronal avalanches with power-law distributed sizes and time durations as observed in spontaneous brain activity. When the excitatory synaptic strength is further increased, the dynamics changes to state III in which the bursting of the neurons becomes incoherent, and the time-binned firing rate of the whole network is approximately time-independent. In addition, we find that adaptation is crucial for the existence of state II: when the network is in state II, it would undergo transition to state III if adaptation is weakened. Hence, state II emerges when there is a balance between excitatory coupling and adaptation.

Modulation of Two-Dimensional Exciton Emissions by (Gold Nanodisk)-on-Mirror Cavities

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The plasmonic properties of metal nanoparticles are highly dependent on their morphology and size. Pseudo-two-dimensional (2D) gold nanodisks (NDs) possess atomically flat surfaces, which permit strong interactions with the substrate underneath and benefit the construction of layer-stacking hybrid structures with rich optical modes. Dark excitons in transition metal dichalcogenide (TMDC) monolayers (MLs) are promising candidates for the Bose–Einstein condensation and can be applied for quantum information processing due to their long lifetime. Their emissions therefore have been investigated under critical conditions such as cryogenic temperature and high magnetic field due to their weak interactions with light. One way to enhance the emission efficiency of dark excitons is to insert TMDC MLs into an out-of-plane electromagnetic field with which the dipole moments of dark excitons align. Here, we brighten the dark excitons of WSe2 ML at room temperature with hybrid structures constructed by (Au nanodisk)-on-mirror nanocavities with WSe2 MLs sandwiched in between. Highly tunable in-plane magnetic modes are excited by precisely controlling the diameters of Au NDs. The in-plane plasmon modes of the (Au ND)-on-mirror nanocavities give rise to a large area of the greatly confined out-of-plane electric field within the WSe2 ML, which boosts the radiative decay rates of dark excitons through the Purcell effect. The in-plane mode is highly sensitive to the tilt angle of the Au NDs. The double peak features with a large peak spacing in scattering are excited by normal incident light with their polarization along and perpendicular to the tilt axis. Our investigations will contribute to the development of TMDC-based smart sensors and compact nanophotonic devices.

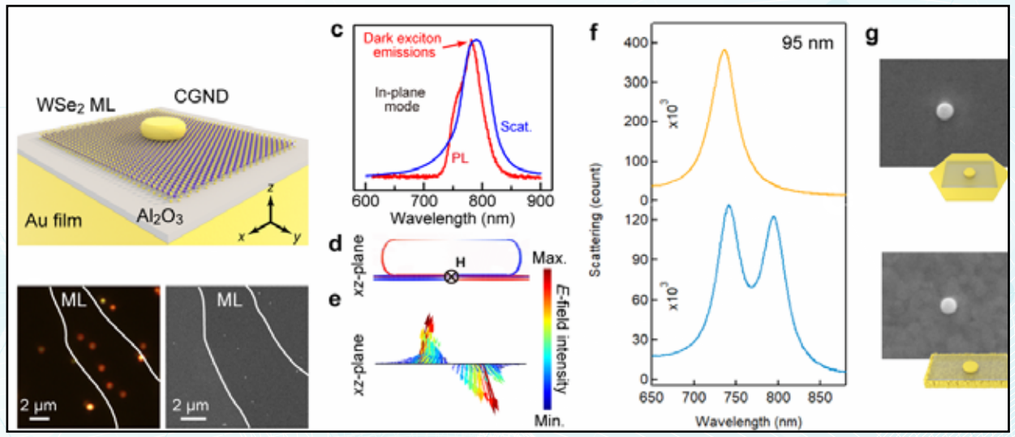

Figure caption: (a) Schematic of a (WSe2 ML)-sandwiched Au nanodisk-on-mirror structure. (b) Dark-field scattering (left) and corresponding SEM (right) images. (c) Photoluminescence (PL) and scattering spectra under the modulation of the in-plane cavity mode. (d,e) Charge distribution contours and electric field distribution contours of the in-plane modes at 780 nm. (f) Scattering spectra for Au NDs with the same diameter deposited on flat Au microplate (up) and E-beam evaporated rough Au film (down), respectively. (g) SEM images and schematics for structures measured in (f). Up: on flat Au microplate, down: E-beam evaporated rough Au film (down).

Test for Network Independence with Distance Correlation

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Network models have received increasing popularity in recent years because of the growing availability of large-scale social network data and the need to model complex systems such as meteorology and biology. First, the distance covariance of a set of random vectors in a network is discussed by extending the existing work on distance covariance, where the latter has the crucial feature that it equals zero if and only if two random vectors are independent and thus can detect arbitrary types of non-linear associations. The proposed measure includes special cases such as the auto-distance covariance in time series and random fields. Based on the new measure, a new test for the independence of network data is developed. In particular, a Ljung-Box-type test for associative autocorrelation in a graph-structured network setting is proposed. Extensive simulation studies with various dependency structures illustrate the test's usefulness. The proposed method often outperforms many prevalent ones in the literature, especially when the data exhibits a non-linear relationship. The asymptotic distributions of the test statistic is established with the aid of incomplete U-Statistics. The test is applied to study the goodness-of-fit of a fitted network model based on the residuals. An example is demonstrated using England and Wales's climate wind speed data, fitted by a generalized network autoregressive model with spatial and temporal components.

Optimally Jittered Inference of Jump for High-Frequency Data

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Precisely estimating the degree of variability of a stochastic process with high- frequency observations is of great importance in financial economics. While bipower variation and quadratic variation are commonly employed measures of volatility, only the former demonstrates robustness in the presence of process jumps. In this paper, we introduce the concept of autobipower variation, which serves as a fundamental building block for constructing more precise estimators of integrated variance of the stochastic volatility process and a set of feasible tests for detecting potential jumps. We also propose the principle of optimal jittering for inferring jumps using quadpower variation. This technique is proved to be effective in enhancing the efficiency of estimators and the power of tests. In particular, the asymptotic variance of our proposed test statistic is less than one-third of that of the classical test based on bipower. Implementationally, we show that the statistical procedure of optimal jittered inference of jumps is universal and does not rely on any data-dependent tuning parameters. A particularly intriguing result is that using exactly three lags to form an average is proved to achieve the highest efficiency in our approach.

Keywords: jump process; bipower variation; quadpower variation; variance reduction; stochastic volatility.

A Nonparametric Contrastive Learning Approach to Density Estimation

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In this paper, we propose a novel method for nonparametric density estimation titled nonparametric noise contrastive estimation (abbreviated as NNCE thereafter). Deep neural networks are used in nonparametric function approximation. Non-asymptotic upper bound for the excess risk under L_{2} loss has been established, which has been shown to achieve the minimax optimal rate of convergence. Moreover, our method shows inherent adaptivity for low-dimension structures of data with a faster convergence rate under the compositional structure assumption. To illustrate the performance of NNCE, comprehensive numerical studies has been conducted with comparison to the state-of-the-art nonparametric density estimation methods.

Large Scale Bayesian Computation with Stochastic Gradient Barker Jump

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Rapid and scalable Markov Chain Monte Carlo (MCMC) algorithms for posterior sampling are crucial for effective Bayesian learning and inference. In this paper, we introduce the Stochastic Gradient Barker Jump (SGBJ), an efficient algorithm for posterior sampling that leverages the efficiency of stochastic gradient computation to sample from differentiable posterior distributions. The SGBJ algorithm employs stochastic gradient approximations for locally informed Markov Chain Monte Carlo proposals, integrated within a scalable computing framework. Notably, our method demonstrates excellent scalability with increasing data dimensions and exhibits robustness to hyperparameter (mainly step size) tuning. A significant advantage of the SGBJ algorithm is its consistent computational complexity per iteration, ensuring both fast and scalable performance. We provide a theoretical analysis of the algorithm, including non-asymptotic error bounds, affirming that it retains scalability with dimensional growth comparable to existing methods such as Stochastic Gradient Langevin Dynamics (SGLD). Empirical results from numerical experiments validate the robustness and scalability of our method in high-dimensional settings, with practical applications illustrated through Bayesian learning tasks using deep neural networks for image recognition. In conclusion, the proposed sampler provides a robust and scalable sampling framework that can be applied under large-scale Bayesian computing to boost the performance of complicated probabilistic models such as Bayesian deep learning.

Investigating Climate Change and Urbanization Impacts on Summer Thermal Environment in Greater Bay Area of China

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The effects of near-future (2035-2064) climate change and urbanization are simulated on the thermal environment in 10-18 July 2007 over the Guangdong-Hong Kong-Macao Greater Bay Area (GBA). Tropical storm "*Man-yi*" has developed over the western North Pacific (WNP) region during the study period, and its storm track is well simulated compared to reanalysis and best-track data. It is found that the surface temperature anomaly is higher near the coast under climate change, whereas it is higher away from the coast under urbanization. These anomaly patterns are attributed to the intensified storm due to climate change and stronger local circulation due to urbanization, respectively. Under the climate change simulation, the intensified storm induced anomalous northwesterly to the GBA, suppressing the summer sea breeze, which is supposed to serve as a cooling agent. On the other hand, the urbanization effect amplifies the land-sea contrast of temperature, which strengthens the sea breeze. It is also found that anomalous surface temperatures peak at 6 am and 9 pm for climate change and at 1 am and 7 pm for urbanization, where both typically contribute to a hotter nighttime. Urban regions experience a higher increment in both daily maximum (T-max) and daily minimum temperatures (T-min), but the urban-rural contrast is more prominent in T-min under climate change, while it is more prominent in T-max under urbanization.

Revealing Surface Water System on the Greenland Ice Sheet Using Artificial Intelligence

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The Greenland Ice Sheet is the largest single contributor to global sea level rise. Every summer, surface water on the ice sheet is produced by widespread ice and snow melting, then get transported and stored in the surface water system (supraglacial rivers, lakes, moulins, and crevasses), and finally enters the ocean via proglacial and subglacial pathways. Surface water largely drives the mass loss of the ice sheet, and couples crucially with dynamical ice motion. However, this diverse, complex, and highly dynamic river system remains poorly studied, mainly due to the high logistic cost for in-situ measurements and the inability of current satellite mapping methods.

To address this problem, this study proposes the first known automated method to map the Greenland surface water system from satellite images, powered by artificial intelligence. Firstly, we train a semantic segmentation neural network called DeepLabv3+ to map the water-filled crevasses region. Next, we train another DeepLabv3+ network to map inter-connected supraglacial rivers and lakes. Finally, we identify moulins (vertical water pathways) from inter-connected supraglacial rivers and lakes.

The prototype of this AI-powered algorithm exhibits great potential in mapping Greenland surface water system. In the future, this algorithm will be applied to multi-temporal and large-scale satellite images across the entire melting zone of Greenland, to further provide the first characterization on the spatial-temporal evolution of the Greenland water system. These new results will provide key parameters of climate models to better simulate the ice mass balance from the past to the future.

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