CCRS Newsletter

Issue 9, December 2025

Highlights in This Issue

MOU signing ceremony for the Climate and Weather Research Alliance Singapore (CAWRAS): (Front row, L–R) Ms Koh Li-Na (NEA), Prof Lim Keng Hui (A*STAR), Prof Louis Phee (NTU Singapore), Prof Liu Bin (NUS); (Back row, L–R) Mr Lim Tuang Liang (MSE), Dr Janil Puthucheary (Senior Minister of State for Sustainability and the Environment), Dr Michel Jarraud (Chairman, MSS International Scientific Advisory Panel)

METEOROLOGICAL SERVICE SINGAPORE
Centre for Climate Research Singapore

Contents

Word from the Director

Welcome to the ninth edition of the CCRS Newsletter!

2025 has been a landmark year for CCRS, marked in particular by the launch of the Climate and Weather Research Alliance Singapore (CAWRAS) in September and significant progress on several research fronts most notably urban-scale modelling and artificial intelligence (AI).

The CAWRAS is a new, national research platform that brings together the National Environment Agency (NEA – CCRS' parent agency), the Agency for Science, Technology and Research (A*STAR), Nanyang Technological University (NTU), and the National University of Singapore (NUS) to advance tropical climate and weather research for Singapore and Southeast Asia. Further details are provided in this newsletter.

I'm particularly pleased to share our progress in ultra-high resolution climate modelling. Building on the success of Singapore's Third National Climate Change Study (V3), we have pushed the boundaries of climate modelling still further through new 100-m resolution climate projections for Singapore using our 'uSINGV' urban model. This level of detail enables users to study climate change impacts at the neighbourhood level, informing urban planning and heat mitigation strategies in our dense tropical city-state.

Our commitment to innovation continues with significant advances in AI-based numerical weather prediction (AI-NWP). Through comprehensive benchmarking of global AI-NWP models and development of our own regional data-driven model, we are exploring how AI can enhance weather prediction for our unique tropical conditions.

International collaboration remains central to our strategy. We welcome Dr Jeff Polton from the UK's National Oceanography Centre as CCRS' first Long-Term Visiting Scientist. His expertise in marine modelling will boost our coupled ocean-atmosphere research, essential for understanding the complex climate of the Maritime Continent region.

In this issue, you will find detailed coverage of these developments, along with updates on our growing team and achievements of our scientists on the international stage.

We hope you find this newsletter informative. Please feel free to share it with your colleagues and friends, and don't forget to follow us on LinkedIn. Happy reading!

Professor Dale Barker
Director,
Centre for Climate Research Singapore

New National Alliance to Advance Tropical Climate and Weather Research in Singapore

A new chapter in tropical climate and weather science research began on 5 September 2025 with the official launch of the Climate and Weather Research Alliance Singapore (CAWRAS). Led by CCRS, this national research platform brings together the National Environment Agency (NEA), Agency for Science, Technology and Research (A*STAR), Nanyang Technological University, Singapore (NTU Singapore), and the National University of Singapore (NUS) to advance tropical climate and weather research for Singapore and Southeast Asia and to nurture the local talent pipeline in weather and climate science.

A timely response to climate challenges

Dr Janil Puthucheary, Senior Minister of State (SMS) for Sustainability and the Environment, was the Guest-of-Honour at the launch event attended by more than 150 participants from Singapore's research and policy communities. In his opening remark, SMS Janil emphasized the critical timing of the establishment of CAWRAS.

"We are experiencing the warmest years since global temperature records began in 1850, with key climate change indicators such as global mean sea levels and greenhouse gas levels reaching record high levels," SMS Janil noted. "Weather and climate shape every aspect of our lives, from the food that we eat to the clothes that we wear. Understanding these weather patterns goes beyond just improving our everyday convenience; it is a crucial step towards enhancing our resilience against the serious threats of a changing climate."

Dr Janil Puthucheary, Senior Minister of State for Sustainability and the Environment, delivered his opening remark at the launch of the Climate and Weather Research Alliance Singapore (CAWRAS) on 5 September 2025.

Formalising national collaboration

The event saw the signing of a Memorandum of Understanding (MOU) between the four partner institutions, cementing their commitment to collaborative research (see front cover photo). A symbolic launch mechanism with weather element discs representing rain, wind, sun, cloud and lightning was employed as a fitting metaphor for the climate and weather phenomena that CAWRAS will study.

The official launch of the Climate and Weather Research Alliance Singapore (CAWRAS) by Senior Minister of State Dr Janil Puthucheary (eighth from right) and representatives from partner institutions, joined by members of the CAWRAS Scientific Working Group.

As its first major initiative, CAWRAS will implement the $25 million Weather Science Research Programme (WSRP), which includes four key Research Clusters in Observations, Next-Generation Models, Regional Reanalysis, and Post-Processing.

Ten research projects have been awarded under the WSRP, leveraging cutting-edge technologies including artificial intelligence (AI) and high-resolution physical modelling to address unique tropical weather prediction challenges. One project will use AI to develop more skillful predictions of convective hazards, potentially enhancing forecasts of heavy rainfall and strong winds for sectors such as aviation, flood protection and port operations. Another project will further develop CCRS' coupled ocean-atmosphere-wave-land modelling system, for use in enhanced projections of future regional climate whilst potentially also improving forecasts of local weather phenomena such as Sumatra squalls. For more information on the WSRP, refer to the CCRS Newsletter Issue 8 (June 2025).

New collaborative platform for climate and weather research

Supporting all CAWRAS research activities is the new Climate and Weather Research and Evaluation Testbed (CAWRET), hosted by A*STAR in partnership with the National Supercomputing Centre (NSCC) Singapore. CAWRET provides researchers with access to comprehensive observation datasets, advanced modelling capabilities, and supercomputing resources essential for compute-intensive weather and climate research. CAWRET will help facilitate cross-institute collaborative research through common configurations (domain of interest, resolution, time periods, etc.), enabling robust evaluation of new weather prediction capabilities against standard benchmarks (e.g. impact on forecast skill of research advances measured against MSS' standard scorecard of key weather parameters and forecast ranges), helping to enhance Singapore's weather resilience.

Looking ahead

Beyond the WSRP, CAWRAS will expand its scope in future to include climate research on longer timescales, potentially encompassing monthly to decadal prediction, updated 'V4' regional climate projections, and sea-level research. As Singapore continues to face the challenges of climate change, CAWRAS represents a significant step forward in building the scientific capabilities needed to enhance weather prediction and climate resilience for the nation and the broader Southeast Asia region. Find out more about CAWRAS via the corporate video and brochure.

QR to CAWRAS video

QR to CAWRAS brochure

From Kilometre-Scale to 100-Metre Resolution Projections of Singapore's Future Climate

Following the release of Singapore's Third National Climate Change Study (V3) in January 2024, CCRS has taken local climate change projections to an unprecedented level of details. While V3 provides 2-km high-resolution climate change projections for Singapore and the western maritime continent region, CCRS has initiated a pilot study to zoom in even further. In this study, we downscale V3 projections to an ultra-high 100-m resolution through the 'uSINGV' urban-scale modelling configuration of the Unified Model (UM) developed in collaboration with international partners (e.g. the UK Met Office) over the past 5 years. Figure 1 shows the 2-km V3 domain and 100-m uSINGV domain.

The new urban-scale model represents a significant step-up in CCRS' climate projection capabilities, enabling stakeholders and decision makers to examine how climate change could affect individual districts in Singapore.

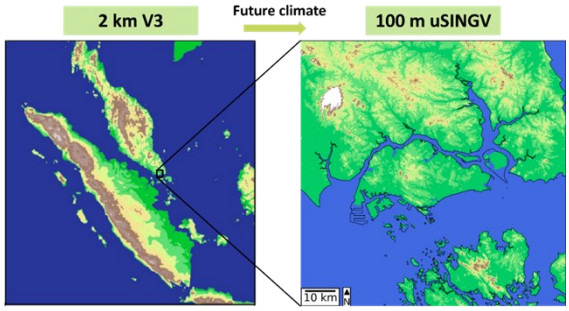


Figure 1. *Downscaling 2-km climate projections from Singapore's Third National Climate Change Study (V3) to 100-m resolution through uSINGV, CCRS' urban modelling system.*

Meet uSINGV—Singapore's ultra-high resolution urban climate model

The uSINGV is a sub-km resolution (100–300 m) weather and climate model research configuration of the UM-based SINGV system, used at lower resolution at CCRS in both operational numerical weather prediction (1.5/4.5 km) and the latest V3 regional climate projections (2/8 km).

The uSINGV model features a single-layer urban canopy model[1] called MORUSES (Met Office-Reading Urban Surface Exchange Scheme) that represents the effects of urbanisation on surface processes affecting heat, moisture, radiation and winds.

Dr Song Chen is the Head of CCRS' Core Modelling Development Branch under the Department of Weather Research. His research utilizes CCRS' urban model in both weather prediction mode and to enhance understanding of Singapore's urban climate.

Several physical schemes have been specifically tuned for tropical urban environments at the urban scale. For example, we tuned the boundary layer (lowest ~1 km of the atmosphere) mixing scheme to improve model accuracy at the urban scale while reducing computational expense. The new mixing scheme blends a parametrization approach (commonly used in km-scale simulations to represent sub-grid-scale processes) with a Large Eddy Simulation scheme, which explicitly resolves the complex interactions between the urban environment and lower atmosphere.

Over the past few years, key datasets such as the Land Use Land Cover, Urban Morphology and Anthropogenic Heat have been developed and updated for Singapore. We have incorporated these latest datasets in uSINGV, which help to provide more realistic representations of urban environment.

Studying Singapore's hottest days under climate change

For this urban-scale future climate pilot study, we selected the top 15 hottest days from both historical (1994-2015) and future periods (2080-2099). The goal was to assess how climate change might influence the urban heat island (UHI) effect, a phenomenon where urban areas experience higher temperatures than rural areas due to human activities and urban infrastructure.

[1] Represents the urban environment as one layer that captures the average effects of buildings, roads and other urban features on the atmosphere, rather than representing individual building details within the urban canopy.

The ultra-high-resolution uSINGV urban model requires a much smaller time step than km-scale versions to maintain model stability. Due to the high computation demand of the simulations, for this pilot study, we used uSINGV to downscale the climate data for these 15 hot days. Future work will extend the simulations to more cases.

Firstly, we used the V3 project's 2-km historical downscaling run of the ERA5 global reanalysis[2] to run 100-m uSINGV simulations for the selected hottest days in the historical period to assess the model's performance. To consider extreme scenarios, the study used V3 data downscaled from the UK Earth System Model (UKESM) under the high emissions pathway (SSP5-8.5) to drive uSINGV for the future period.

North vs South—Singapore's varying urban heat future

With the 100-m uSINGV downscaled data, we computed the UHI intensity against a reference rural site, calculated as the difference between the urban temperature and rural temperature. Figure 2a shows the diurnal cycles of UHI intensity. Results from the future 100-m uSINGV downscaling using UKESM-driven V3 data show overall good agreement with results from historical simulations, but slightly lower UHI intensity over the Singapore main island during the night.

Both the historical and future scenarios show that the UHI effect mostly occurs during the nighttime, with negative UHI intensities (i.e. the island-wide averaged temperature is lower than the reference rural site) occur during the daytime. In the future scenarios, the simulations suggest that the overall UHI intensity may decrease slightly. Further investigations reveal that the overall negative UHI intensity during the daytime is due to strong sea breezes that cool southern parts of Singapore (Figure 2b). The northern part of Singapore and the adjacent city of Johor Bahru remain hot with higher UHI intensity. This study indicates the spatial diversity of UHI for Singapore and its complex coupling mechanism with sea breeze.

[2] Reanalysis provides the most complete picture currently possible of past weather and climate by blending a large amount of observations with modern weather forecasting models. It describes the recent history of Earth's climate system more comprehensively than observations. The reanalysis data used in V3 is ERA5, the latest climate reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF).

Next steps in CCRS' urban climate research

As Singapore continues to develop as a dense tropical city-state, understanding climate change impacts at the neighbourhood level becomes increasingly important for maintaining liveability and resilience.

This pilot study represents just the beginning of CCRS' exploration into ultra-high resolution urban climate modelling and simulation. Further research is planned through the Weather Science Research Programme (WSRP). Additional uSINGV simulations are planned to continue investigating Singapore's future urban climate, with the aim to provide unprecedented detail that could inform urban planning and heat mitigation strategies in Singapore.

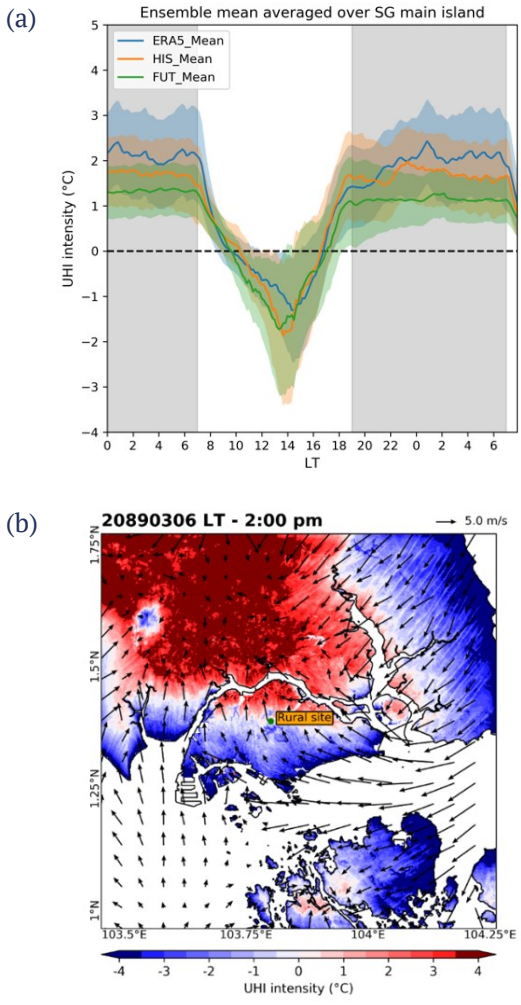


Figure 2. *(a) Diurnal cycles of the urban heat island (UHI) intensity over Singapore main island downscaled using V3 data driven by historical reanalysis data (ERA5), historical UKESM data (HIS), and future UKESM data (FUT), where solid lines are the mean values among the top 15 hottest days and shades are the standard deviations. LT in the horizontal axis refers to local time. (b) UHI intensity contour plot with wind vectors near the surface for one of the future hottest days. The reference rural site at the centre of Singapore is highlighted.*

Benchmarking and Building: CCRS' AI-driven Weather Prediction Strategy

Weather prediction is undergoing a great transformation with the rapid advancement of artificial intelligence-based numerical weather prediction (AI-NWP) models. In 2025, CCRS has begun examining existing global AI-NWP models' performance in the Southeast Asia region and exploring strategies to further develop regional AI-NWP capabilities, supported by comprehensive assessments.

In 2025, we have focused our efforts on a number of complementary initiatives aimed at enhancing regional weather prediction capabilities:

1. Benchmarking open-source AI-NWP models: Evaluating the performance of selected pre-trained models over the entire 2024 period using common initial conditions[3], and the same verification metrics / observation datasets used in our operational NWP performance monitoring.
2. Developing a regional data-driven weather prediction system using a stretched-grid model: Training a machine learning (ML) model to provide high-resolution and high-fidelity weather predictions that incorporate the information from global to regional scales.
3. Collaborating with local universities through the Weather Science Research Programme (WSRP) to develop a regional foundation AI model for weather and climate applications.

These efforts reflect CCRS' commitment to exploring innovative, cost-effective technologies that can support operational needs in Singapore and the wider Southeast Asia region. These studies represent a significant step forward in CCRS' strategy to harness AI and data-driven methods for tropical weather prediction.

Dr Arun Ramanathan is a Research Scientist in the Numerical Weather Prediction (NWP) Branch in CCRS' Department of Weather Research. His work focuses on harnessing artificial intelligence (AI) to enhance NWP for Singapore and the Southeast Asia region.

Pluto Chui is a Research Scientist in CCRS' NWP Branch. His work focuses on AI regional data-driven model development as well as the operational implementation of CCRS' first machine learning (ML) based rainfall nowcasting system.

Benchmarking global AI-based models for Southeast Asia

How we evaluated the models

We designed a benchmarking workflow that balances scientific rigour with practical feasibility (Figure 3) to assess the potential of selected open-source AI-NWP models (Table 1) for operational use in Singapore.

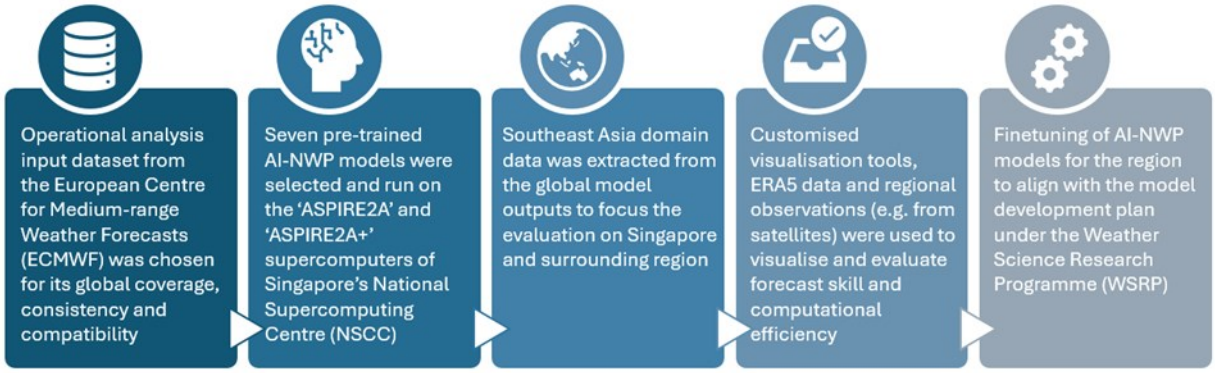


Figure 3. *The benchmarking workflow was structured to evaluate the forecast skill and computational efficiency of selected pre-trained AI-NWP models, using a combination of global reanalysis data, regional observations, and visualisation tools tailored for evaluation.*

[3] From the analysis from the European Centre for Medium-Range Weather Forecasts (ECMWF)

Table 1. *A summary of the selected AI-NWP models for the benchmarking exercise.*

Model	Provider	Architecture	Training data
Panguweather	Huawei	3D Earth-specific transformer	ERA5
FourcastnetV2	Nvidia	Vision Transformer with Fourier Neural Operator	ERA5
Graphcast	Google Deepmind	Multi-Mesh Graph Neural Network (GNN)	ERA5
AIFS	ECMWF	GNN-based	ERA5
Aurora	Microsoft	Spatiotemporal Transformer foundation model	ERA5
Prithvi	IMB and NASA	Vision Transformer foundation model	MERRA-2[4]

Key findings from the benchmarking exercise

The evaluation included both subjective verification through visual inspection of model outputs (Figures 4 and 5), and objective verification using metrics which provide deeper insights into model performance and behaviour, e.g. root mean square error (Figure 6), kinetic energy spectra.

We found significant differences in model performance across different variables. Figure 4 provides a case study of relative performance, hinting that Graphcast and AIFS provide more realistic forecasts of wind (divergence) compared to the corresponding ERA5 reanalysis. For the same Sumatra squall case, Graphcast and AIFS provided reasonable rainfall prediction (Figure 5). However, all off-the-shelf AI models lack the intensity and "sharpness" of forecasting detailed rainfall patterns reported in similar studies.

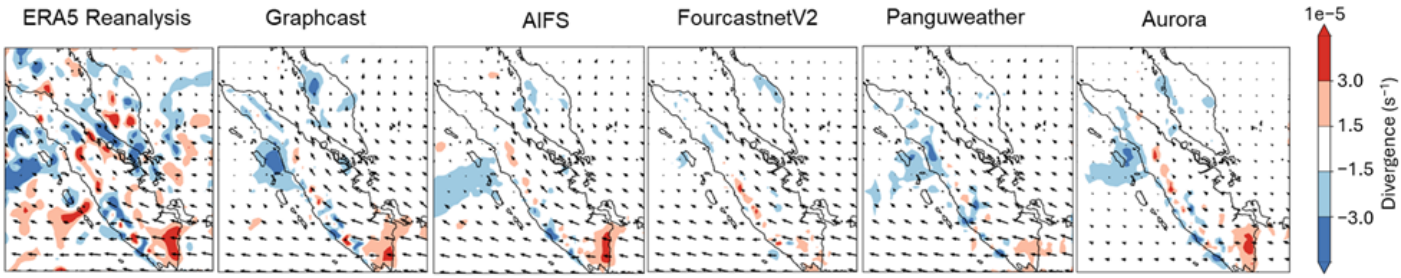


Figure 4. *Wind divergence forecasts from selected AI-NWP models, 24 hours lead-time, valid at 8am SGT on 9 Aug 2024 for the western Maritime Continent region. The ERA5 reanalysis data (left panel) is used as a benchmark for subjective and objective evaluation of model performance.*

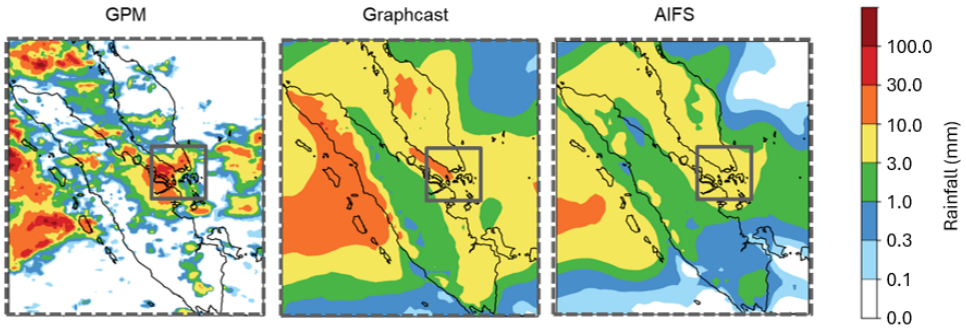


Figure 5. *Forecasted 6-hourly accumulated rainfall from selected AI-NWP models, 24-hour lead-time, valid at 2pm SGT on 9 Aug 2024 for the western Maritime Continent region. The satellite-derived Global Precipitation Measurement (GPM) rainfall data product was used as a benchmark for evaluation of model performance.*

[4] The latest global atmospheric reanalysis dataset produced by NASA

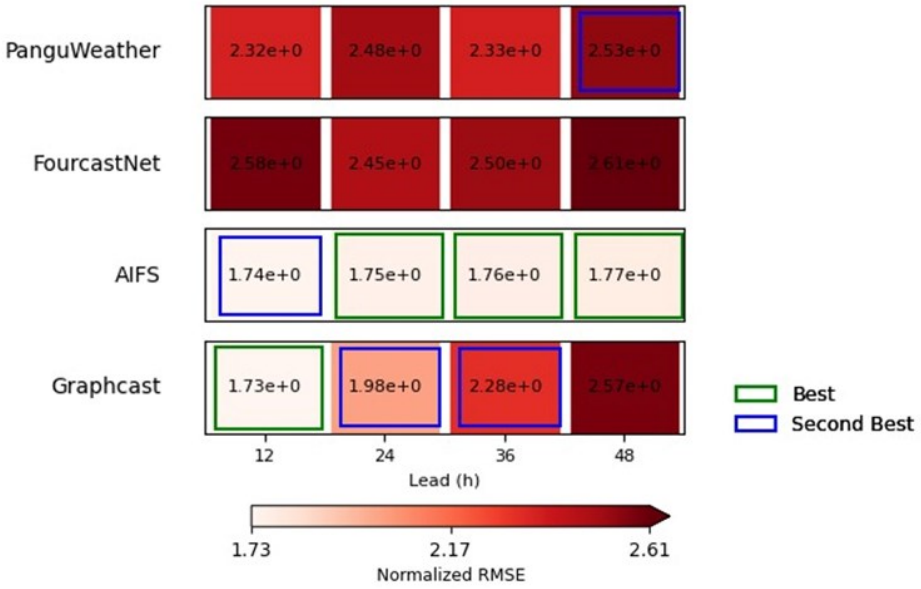


Figure 6. *Normalised root mean square error (NRMSE) for the outputs from selected AI-NWP models for the Southeast Asia region throughout the year 2024. The NRMSE captures both direct weather variables (e.g. rainfall) from the model outputs and derived dynamic metrics (e.g. atmospheric circulation patterns) computed from these outputs, allowing fair comparison of model performance against the ERA5 data.*

Our initial evaluation of the quality of locally run, off-the-shelf AI models has highlighted the well-known computational advantages of AI-NWP models, due to their fast inference and low resource requirements compared to traditional NWP models.

In the next phase of the work, we will explore fine-tuning AI models for the tropical environment, develop techniques to blend high-resolution predictions from multiple models, and build a forecaster portal that provides real-time access to AI-NWP outputs for operations.

Developing a regional data-driven stretched-grid weather model

The stretched-grid approach

While testing existing global AI-NWP models provides valuable insights, it is well known that those models do not capture the fine-scale features of Singapore's weather in their training datasets. CCRS is therefore developing our own regional data-driven weather prediction model, adopting a stretched-grid model (SGM) in initial tests. The SGM approach uses a variable resolution grid that defines a higher resolution grid over Singapore and Southeast Asia while maintaining lower resolution over the rest of the global domain (Figure 7).

The SGM approach has the advantages of effectively incorporating large-scale information from the global domain to the specific region of interest to enhance the performance of local weather prediction, while reducing the computation cost still further beyond the local domain of interest.

Figure 7. *A stretched grid showing the boundary between global and regional domains.*

Using advanced machine learning framework

To develop the regional AI-NWP model for the Singapore region, we adopt the state-of-the-art 'Anemoi' ML framework. The system uses a Graph Neural Network (GNN) based model to accommodate the variable resolution stretched-grid configuration. GNN excels at learning relationships between data in an unstructured grid.

We trained the regional AI-NWP model on a combination of global ECMWF ERA5 reanalysis data at 31-km resolution and MSS' operational SINGV-DA deterministic NWP system output data at 1.5-km resolution. This training approach allows the model to learn from both global weather patterns and detailed local patterns, so that the model can produce more accurate short -range weather predictions at km-scale with hourly updates for the Singapore region (Figure 8 shows preliminary results).

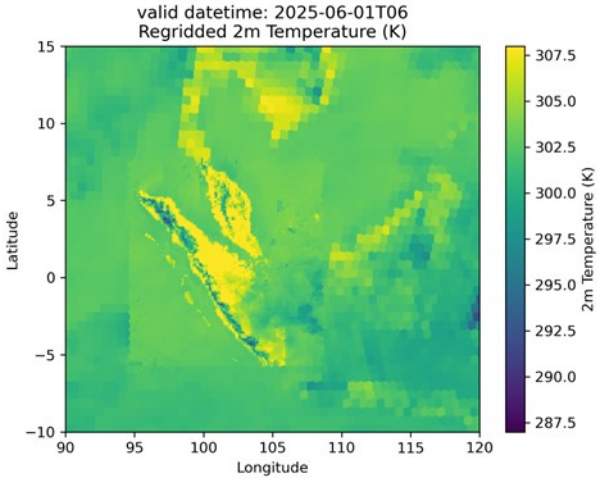


Figure 8. *Preliminary prediction results from the regional data-driven stretched-grid model over Singapore.*

The potential time savings of AI-NWP vs traditional NWP are remarkable. Traditional physics-based models require approximately one hour to solve the complex differential equations numerically to generate short-range regional weather predictions. In contrast, the data-driven model, trained on abundant data, can provide high-fidelity weather predictions within seconds or minutes. This is a significant improvement for time-sensitive applications such as emergency response, aviation and maritime operations.

Early success and next steps

Early results from both initiatives show significant promise. We will continue refining both off-the-shelf AI-NWP benchmarking and CCRS' own find-scale AI model(s). For the AI-NWP benchmarking, next steps include fine-tuning models, stitching high-resolution models, and building a forecaster portal. The SGM development will continue with plans to increase spatial and temporal resolutions further, extend training dataset duration, expand variable types, and explore multi-GPU training techniques to handle larger datasets more efficiently. At the same time, we will continue to work closely with our international and local university partners to further align research towards high-resolution regional AI-NWP development.

These efforts demonstrate CCRS' forward-looking, comprehensive approach to advancing weather prediction capabilities for Singapore and the Southeast Asia region. By leveraging AI and data-driven approaches and developing custom solutions, CCRS aims to deliver more accurate, timely and locally relevant predictions, enhancing resilience and preparedness across sectors impacted by weather.

Making Waves in Marine Modelling: CCRS Welcomes Its First Long-Term Visiting Scientist

This year, CCRS is delighted to welcome our very first Long-Term Visiting Scientist (LTVS), Dr Jeff Polton from the UK's National Oceanography Centre (NOC), Liverpool.

The newly established CCRS LTVS programme brings leading scientists from local and international universities and weather and climate research institutes to work with CCRS on research projects (typically one to three years). These collaborations are carefully selected to align with CCRS' strategic priorities and to strengthen Singapore's capabilities in climate and weather research.

Dr Danielle Su is a Research Scientist in CCRS' Core Modelling Development Branch. Her research focuses on the development and process-based evaluations of ocean and coupled modelling. She also works with local and regional collaborators to align observational and regional modelling efforts across Southeast Asia.

Over the next three years, Dr Polton will work closely with CCRS scientists and local partners to enhance marine modelling capability in Singapore (Figure 9). His work will span marine model development and coupled modelling research to support marine and coupled environmental prediction science in Singapore and the wider Southeast Asia region.

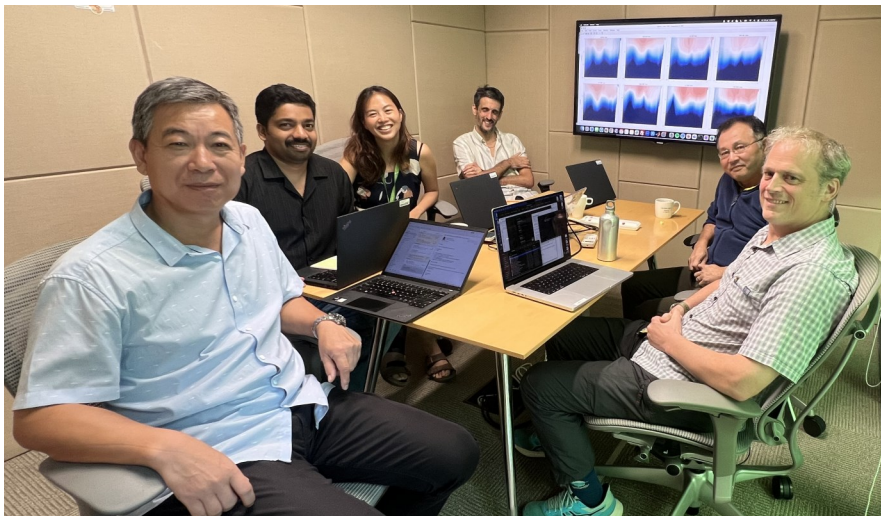


Figure 9. *(L–R) Dr Hugh Zhang, Dr Rajesh Kumar, Dr Danielle Su, Dr Kalli Furtado, Dr Byoung Woong An, Dr Jeff Polton*

Dr Polton currently leads the Ocean–Shelf Processes Group at NOC. His team focuses on developing relocatable and reproducible ocean models and workflows for the Nucleus for European Modelling of the Ocean (NEMO) community. He also leads the UK Joint Marine Modelling Programme's Coastal Ocean Theme, which develops flagship configurations for both research and operational use in collaboration with the UK Met Office.

During his first visit to CCRS in July, Dr Polton worked closely with CCRS scientists Dr Danielle Su, Dr Byoung Woong An and Dr Rajesh Kumar on advancing ocean model development and joint research papers. He also attended the 29th International Union of Geodesy and Geophysics (IUGG) General Assembly in Busan, South Korea, with Dr Su and Dr An, where they presented on their research and visited the Korean Institute of Ocean Science and Technology (Figure 10).

Figure 10. *At the 29th International Union of Geodesy and Geophysics General Assembly in South Korea: (L–R) Dr Byoung Woong An, Dr Rabitah Raud (Senior Lecturer, Universiti Teknologi MARA, Malaysia), Dr Danielle Su, Dr Jeff Polton*

Figure 11. *Dr Jeff Polton shared the UK National Oceanography Centre's modelling capabilities during a CCRS seminar.*

While in Singapore, Dr Polton met with local stakeholders who expressed an interest in investigating subsurface mesoscale processes in the South China Sea. Thanks to these discussions, he was able to begin preliminary work on investigating the oceanic seasonal upwelling dynamics along the Sunda Shelf. He also delivered a seminar at CCRS, where he shared NOC's modelling capabilities and presented research findings from the work carried out during his visit (Figure 11).

A key feature of the LTVS programme is its strong emphasis on co-development with local research institutes and stakeholders. Projects can be designed from the outset in partnership with government agencies and universities so that the research directly addresses local needs. When the LTVS returns to their home institution, the work continues through established workflows, shared tools and ongoing communication, ensuring continuity and long-term impact.

CCRS scientists continue to engage with Dr Polton through online meetings and interact with other members of Dr Polton's NOC team. These sustained interactions support the progress of our joint research and strengthen links with other researchers at NOC and within the wider international marine modelling community.

CCRS is also exploring opportunities to integrate Dr Polton's expertise into CCRS' newly launched Weather Science Research Programme (WSRP) under the Climate and Weather Research Alliance Singapore (CAWRAS). Under the WSRP, the 'Next-Generation Modelling' cluster includes a project focusing on coupled model development, and understanding marine impacts and mesoscale processes. Dr Polton contributes to this effort by sharing his experience in good practices for data repositories, source-code management and community workflows, which are important foundations for robust and collaborative model development.

As our first LTVS, Dr Polton has set a high bar. His generosity with his time, knowledge and ideas has helped to accelerate ongoing projects and lay the foundations for our long-term objectives in regional marine and coupled science. He has already made waves at CCRS, and we are grateful for his commitment and enthusiasm, and for the spirit of collaboration he brings to the partnership.

Boreal Summer Intra-Seasonal Oscillation (BSISO)

Living in Southeast Asia, we may be familiar with the impacts of the Madden-Julian Oscillation (MJO), the main intra-seasonal climate phenomenon of the tropics. Alternating large-scale regions of enhanced and suppressed rainfall propagate slowly eastwards from the Indian Ocean, across the Maritime Continent to the Pacific Ocean, affecting rainfall over the region as they go, particularly through modulating the diurnal cycle.

Dr Simon Peatman is a Senior Research Scientist in CCRS' Seasonal and Subseasonal Prediction (SSP) Branch. His research area is tropical atmospheric processes, with a particular focus on how convective storms respond to large-scale subseasonal drivers such as the Madden-Julian Oscillation (MJO).

Chen Schwartz is a Research Scientist in CCRS' SSP Branch. His work focuses on dissemination of forecasting products at the subseasonal and seasonal timescales, as well as research on the effect of the MJO on subseasonal precipitation over Southeast Asia.

What is the Boreal Summer Intra-Seasonal Oscillation?

However, we may be less familiar with the MJO's cousin, the Boreal Summer Intra-Seasonal Oscillation (BSISO). While the MJO is mainly associated with the boreal (northern) winter months, the BSISO is associated with intra-seasonal variability during boreal summer. Rather than being purely eastward, the BSISO's propagation also has a northward component. The physical mechanisms underpinning this are complex and still the subject of debate, although the Southwest Monsoon and the large-scale gradient in humidity in the north-south direction (Figure 12) likely play major roles.

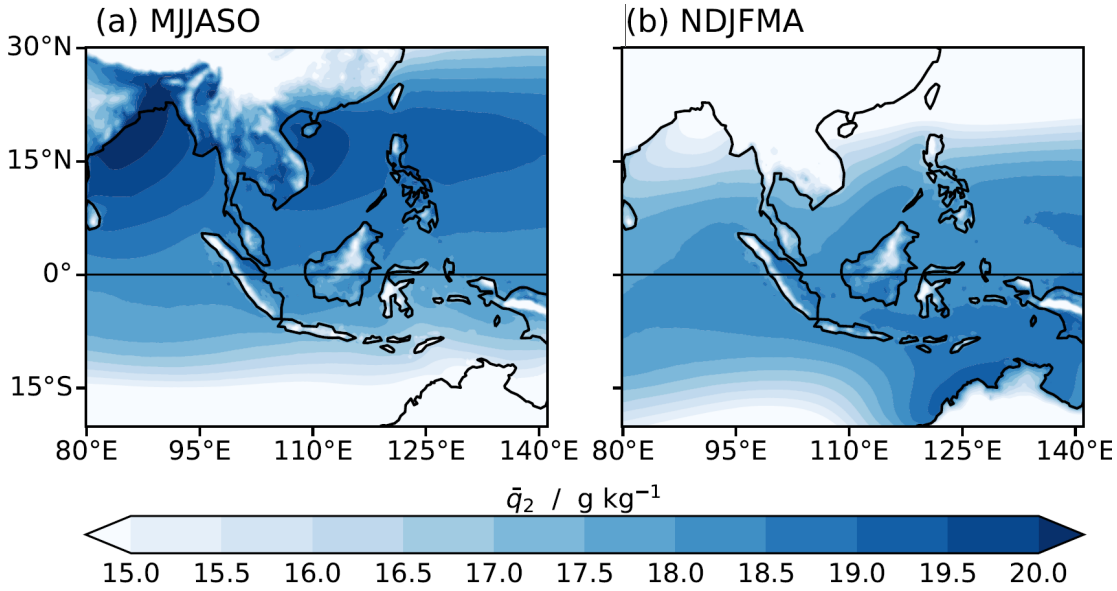


Figure 12. *Mean 2-m specific humidity for (a) May–October, (b) November–April. The large-scale gradient in humidity in the north-south direction in panel (a) is thought to be one of the major causes of the BSISO. Data taken from the ERA5 reanalysis from the European Centre for Medium-range Weather Forecasting.*

Statistical analysis over the Asian summer monsoon region has identified two BSISO modes (Lee et al., 2013). BSISO1 has period 30–60 days and predominantly occurs during May–October, while BSISO2 has period 10–30 days and is typically active during May–June only. Like the MJO, by convention we divide each BSISO mode into eight "phases", each associated with active/suppressed convection over a particular location (Figure 13).

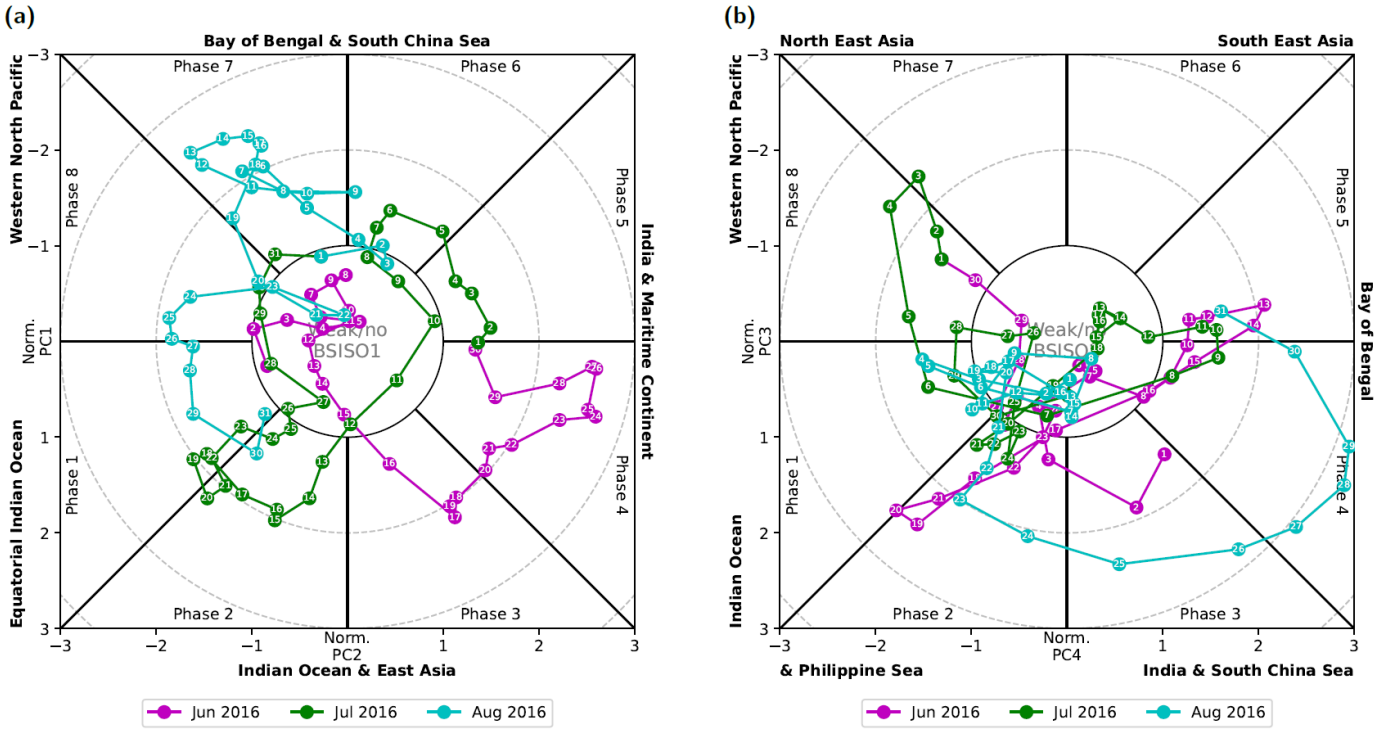


Figure 13. *Example phase diagrams for (a) BSISO1 and (b) BSISO2. Bold text around the edge indicates the location of active convection for each phase.*

Monitoring of the BSISO at CCRS

The Seasonal and Subseasonal Prediction Branch at CCRS provides content for the Southeast Asia Regional Climate Centre Long-Range Forecasting (RCC-LRF) node website. A recently-added page on the BSISO indicates the expected impact of each phase of BSISO1 during May–September, across the region. In the western Maritime Continent, we see a moderate positive correlation between precipitation and BSISO1 amplitude for phases 1–3 (so BSISO1 tends to bring wetter weather during these phases) and a moderate negative correlation during phases 5 and 7. Around Sumatra and the Malay Peninsula, above-normal (upper-tercile) precipitation occurs on more than 50% of phase 2 days (compared to ~33% of days in the climatology, by definition).

At the 25th ASEAN Climate Outlook Forum (ASEANCOF-25) in October 2025, most attendees were unaware of what the BSISO is. Real-time monitoring and forecast tools are already provided by other agencies (notably, APEC Climate Centre [APCC]), but at CCRS we are providing new information for stakeholders to explain the importance of the BSISO for the region. The RCC webpage mentioned above was introduced at ASEANCOF-25 and we will soon add further text on the interpretation and scientific background of the BSISO, to support forecasters and other stakeholders in understanding this important phenomenon.

References:
Lee J-Y, Wang B, Wheeler MC, Fu X, Waliser DE, Kang I-S (2013). Real-time multivariate indices for the boreal summer intraseasonal oscillation over the Asian summer monsoon region. Clim. Dyn., 40, 493–509. 10.1007/s00382-012-1544-4

Science Publications

CCRS continues to contribute to the advancement of tropical weather and climate science through peer-reviewed publications. Selected papers published during the second half of 2025 are listed below, showcasing our work across various aspects of weather and climate R&D.

Patel, Pratiman, Song Chen, Matthias Roth, Humphrey Lean, Aurel Moise, Kalli Furtado, and Hugh Zhang. "Hectometric urban climate modelling over a tropical city." Quarterly Journal of the Royal Meteorological Society (2025): e5075. https://doi.org/10.1002/qj.5075

Kousal, J., C. Pelletier, J. M. C. Denissen, L. Schulte, S. Keeley, P. Dueben, S. G. Penny, R.-S. Park, D. G. Miralles, M. M. Shapkalijevski, A. Valmassoi, I. Renfrew, L. Zampieri, **R. Kumar**, M. Ruiz-Vásquez, J.-P. Schulz, L. Wu, and X. Pedruzo Bagazgoitia, 2025: Numerical weather prediction model coupling—strategies, challenges, and outlook. Bull. Amer. Meteor. Soc. https://doi.org/10.1175/BAMS-D-25-0270.1.

Rajesh Kumar., Amarouche, K., Akpinar, A., Kamranzad, B., & Lemos, G. (2025). Evaluating uncertainty in global wave storm characteristics using CMIP6-derived wave climate simulations with SWAN and WAVEWATCH III models. Global and Planetary Change, 105214. https://doi.org/10.1016/j.gloplacha.2025.105214

Venkatraman Prasanna, Anurag Dipankar, Jianyu Liu, Gerald Lim, Aurel Moise, Xin Rong Chua, Chen Chen, Jianjun Yu, Harika Pavan Raavi, Fei Luo, Muhammad Eeqmal Hassim, Sandeep Sahany, Claudio Sanchez, and Stuart Webster. Evaluating SINGV-RCM for long-term high-resolution climate simulations over Southeast Asia. International Journal of Climatology (2025). https://doi.org/10.1002/joc.8932

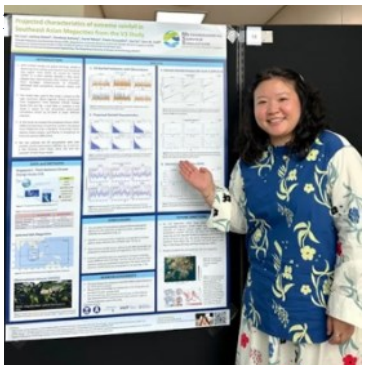
Nguyen H., **Hassim M. E. E.**, Huan J-Y, Chua X.-R., Chen C., Wheeler M. C., Murphy B., Sahany S., Moise A. F., Peatman S. C., Large-scale to local factors influencing Sumatra squalls affecting Singapore. Climate Dynamics, 63(7), 286. https://doi.org/10.1007/s00382-025-07766-w

Peatman SC, Birch CE, Schwendike J, Marsham JH, Howard E, Woolnough SJ, Mustafa JM, Matthews AJ (2025), Physical controls on the variability of offshore propagation of convection from Sumatra, JGR Atmos., 130(7), e2024JD042458. https://doi.org/10.1029/2024JD042458

Events

EPESC-LEADER Science Meeting 2025

On 14–18 July 2025, CCRS Research Scientist Fei Luo attended the joint science between two core World Climate Research Programme (WCRP) activities (i.e. WCRP Lighthouse Activity on Explaining and Predicting Earth System Change [EPESC] and Large Ensembles for Attribution of Dynamically driven ExtRemes [LEADER]) at the APEC Climate Center in Busan, Republic of Korea.



CCRS Research Scientist Fei Luo presented her latest results for projected extreme rainfall characteristics in Southeast Asian megacities in the EPESC-LEADER Science Meeting.

Fei presented her latest research on projected extreme rainfall characteristics in Southeast Asian megacities based on Singapore's Third National Climate Change Study (V3). She also participated in various panel discussions on topics such as climate model errors and attribution methods for extreme events.

Key insights from the meeting highlighted that climate models can have opposite responses to the same forcing, emphasizing the importance of accounting for model errors. This reinforced CCRS' approach of accounting for model errors in V3.

Asia Oceania Geosciences Society 2025 Conference

CCRS scientists actively participated in the Asia Oceania Geosciences Society (AOGS) 2025 Conference held in Singapore on 28 July – 1 August 2025. The annual conference provided opportunities for scientists to discuss and exchange scientific knowledge to address important geo-scientific issues in the Asia Oceania region.

Focusing on the Southeast Asia region, CCRS scientists contributed to multiple sessions covering a broad range of weather and climate research topics, such as:

- Climate adaptation and resilience in coastal Asian cities
- Extreme heat research spanning past, present and future
- Subseasonal to seasonal forecasts and their applications
- The science and prediction of heavy precipitation and flood
- Asian monsoon, extremes and climate change
- Machine learning (ML) and data-driven methods in earth and environmental sciences
- Urban weather, climate and air pollution
- Rainfall variability and extremes over the Maritime Continent
- High-resolution and ML-based numerical weather prediction (NWP)

CCRS Senior Research Scientist Dr Chen Chen shared her work on machine learning emulation of climate change projections.

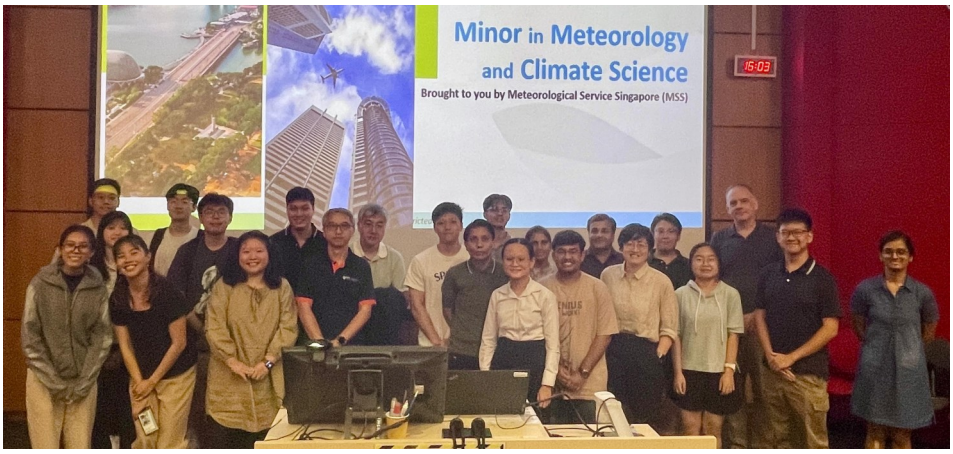
CCRS also ran a booth where scientists engaged with conference participants from across the region and shared insights about our tropical weather and climate research activities.

CCRS Research Scientist Dr Paromita Chakraborty (right) engaged with conference participants at CCRS booth during the Asia Oceania Geosciences Society 2025 in Singapore.

NUS Minor in Meteorology and Climate Science Orientation Programme

In the National University of Singapore's (NUS) Minor in Meteorology and Climate Science Orientation Programme on 7 August 2025, CCRS scientists Dr Xin Rong Chua and Dr Danielle Su shared CCRS' cutting-edge R&D work and internship opportunities, connecting with aspiring weather and climate researchers.

The session generated keen interest from students in climate and weather science. The engagement reinforced CCRS' commitment to nurturing the next generation of climate and weather scientists in Singapore.



CCRS scientists engaged with students from the National University of Singapore during the Minor in Meteorology and Climate Science Orientation Programme.

Capacity Building Workshop on Climate Change and Agriculture in Southeast Asia

On 23–25 September 2025, CCRS contributed to a capacity building workshop on 'Climate Change in the Southeast Asian Region and its Impact on the Agriculture Sector' held in NUS.

The workshop was organised as part of a study endorsed by the ASEAN Ministers on Agriculture and Forestry to analyse climate change impacts on agriculture across ASEAN Member States. Co-organised by the Singapore Food Agency (SFA) and the Tropical Marine Science Institute (TMSI) at NUS, the study focuses on five key crops: cassava, maize, rice, sugarcane and soybean.

Dr Sandeep Sahany, Head of CCRS' Climate Projections and Extremes Branch, delivered a presentation on Singapore's Third National Climate Change Study (V3) and its findings on the impact of climate change on rice production. His talk highlighted how V3 high-resolution climate projections are being utilised to assess future agricultural yields under different climate scenarios.

Senior Research Scientist Dr Anupam Kumar also attended the workshop to network with participants and explore potential collaborations in climate-agriculture research. The event provided valuable opportunities to share CCRS' expertise in regional climate projections while learning about agricultural challenges across Southeast Asia.

In the Capacity Building Workshop on Climate Change and Agriculture in Southeast Asia, Dr Sandeep Sahany, Head of CCRS' Climate Projections and Extremes Branch, shared the impact of climate change on rice production based on the findings of Singapore's Third National Climate Change Study (V3).

2025 HPC Users Symposium

On 25 September 2025, Dr Jeff Lo, Head of CCRS' High Performance Computing Branch, participated in the 2025 HPC Users Symposium organised by the National Supercomputing Centre (NSCC) Singapore. The annual symposium brought together international public sector representatives, industry experts, researchers and users of NSCC Singapore's supercomputers for a day of knowledge sharing and networking.

Dr Lo delivered a presentation titled "Overview of Climate and Weather Research Testbed (CAWRET)". His talk introduced CAWRET as a cornerstone infrastructure supporting Singapore's newly established Climate and Weather Research Alliance Singapore (CAWRAS). He shared how CAWRET would facilitate collaborative research across leading institutions, advancing Singapore's tropical weather and climate research.

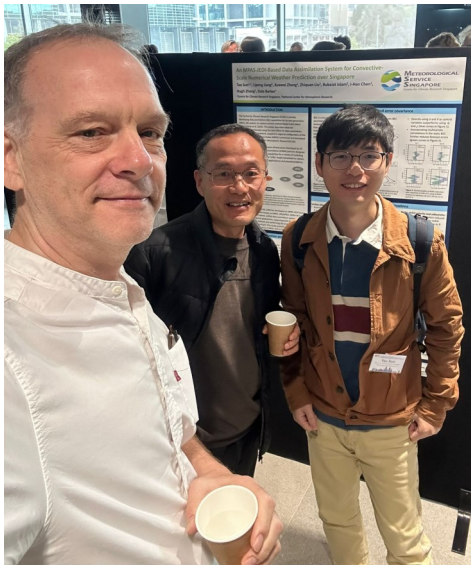
Dr Jeff Lo (left), Head of CCRS' High Performance Computing Branch, shared how CCRS leverages the supercomputers at the National Supercomputing Centre (NSCC) Singapore for its R&D activities.

11th International Symposium on Data Assimilation

CCRS Research Scientist Dr Tao Sun and CCRS Director Prof Dale Barker attended the 11th International Symposium on Data Assimilation (ISDA2025) held on 29 September – 3 October 2025 in Melbourne, Australia. The symposium brought together international experts to discuss challenges and progress in the field of data assimilation, the process by which observations are optimally combined with model data to provide a snapshot “analysis” of the earth system.

In his poster presentation titled ‘An MPAS-JEDI-Based Data Assimilation System for Convective-Scale Numerical Weather Prediction over Singapore’, Dr Sun showcased the ongoing collaboration between CCRS and the U.S. National Center for Atmospheric Research (NCAR) in developing advanced data assimilation capabilities for Singapore's next-generation NWP system, SINGV_NG, within the Joint Effort for Data Assimilation Integration (JEDI), a universal data assimilation framework designed to support multiple Earth system models.

Other than highlighting key technical developments (e.g. modelling background error statistics), Dr Sun also presented CCRS' recent development of radar data assimilation within the framework, which showed promising potential to enhance short-term prediction



CCRS Research Scientist Dr Tao Sun (right) presented his work at the 11th International Symposium on Data Assimilation from 29 September to 3 October 2025 in Melbourne, Australia, with CCRS Director Prof Dale Barker (left) and the Australian Bureau of Meteorology’s Hailin Yan (centre).

Visit by Singapore's Senior Ministers of State for Sustainability and the Environment

On 13 October 2025, CCRS hosted Singapore's Senior Ministers of State for Sustainability and the Environment, Dr Janil Puthucheary and Mr Zaqy Mohamad.

CCRS scientists shared insights into CCRS' comprehensive research portfolio, spanning AI-driven rainfall nowcasting, numerical weather prediction, urban climate modelling, seasonal prediction, and multi-decadal climate change projections. The presentation also highlighted various research initiatives managed by MSS, such as the Climate and Weather Research Alliance Singapore (CAWRAS).

The distinguished guests toured MSS' Upper Air Observatory co-located at CCRS. They were briefed on Singapore's meteorological observing network and how upper-air data collected by weather balloons supports operational weather forecasting and climate research activities.

(L–R) Mr Ang Chieng Hai (Director, MSS), Ms Koh Li-Na (Deputy Chief Executive Officer, MSS), Dr Janil Puthucheary (Senior Minister of State for Sustainability and the Environment), Mr Zaqy Mohamad (Senior Minister of State for Sustainability and the Environment), Prof Dale Barker (Director, CCRS), and Mr Lesley Choo (Director, MSS)

25th ASEAN Climate Outlook Forum

On 27-30 October 2025, CCRS scientists from the Seasonal and Subseasonal Prediction Branch contributed to the 25th ASEAN Climate Outlook Forum (ASEANCOF-25) under the ambit of the ASEAN Specialised Meteorological Centre (ASMC). Hosted online by the Ministry of Water Resources and Meteorology, Cambodia (MOWRAM), the forum focuses on advancing the tailoring of climate services to better meet the diverse needs of users across the ASEAN region.

Dr Paromita Chakraborty, Dr Simon Peatman, Chen Schwartz and Wee Leng Tan prepared and delivered presentations on the following topics.

- Review of ASEANCOF-24 outlook and sharing of latest outlook
- Recap of ASEANCOF-24 training on the Relative Oceanic Nino Index and Indian Ocean Dipole (IOD) watch system
- Updates from the Southeast Asia Regional Climate Centre Long-Range Forecasting node

Participants of the 25th ASEAN Climate Outlook Forum.

V3 Roadshow in Kuala Lumpur

On 27–28 October 2025, CCRS scientists co-organised the CCRS-V3/CORDEX-SEA Downscaling Products and Applications Roadshow in Kuala Lumpur, Malaysia, together with CORDEX-SEA (Coordinated Regional Climate Downscaling Experiment - Southeast Asia) and Universiti Kebangsaan Malaysia.

CCRS scientists Dr Sandeep Sahany, Dr Muhammad Eeqmal Hassim and Dr Jianjun Yu delivered comprehensive presentations covering key topics including findings from Singapore's Third National Climate Change Study (V3) for Malaysia, extreme temperature and heat projections, dengue suitability and food security under climate change, and analysis of extreme rainfall, flood and dry spells analysis.

The roadshow reinforced CCRS' commitment to sharing V3 findings with regional partners and supporting climate resilience efforts across the region.

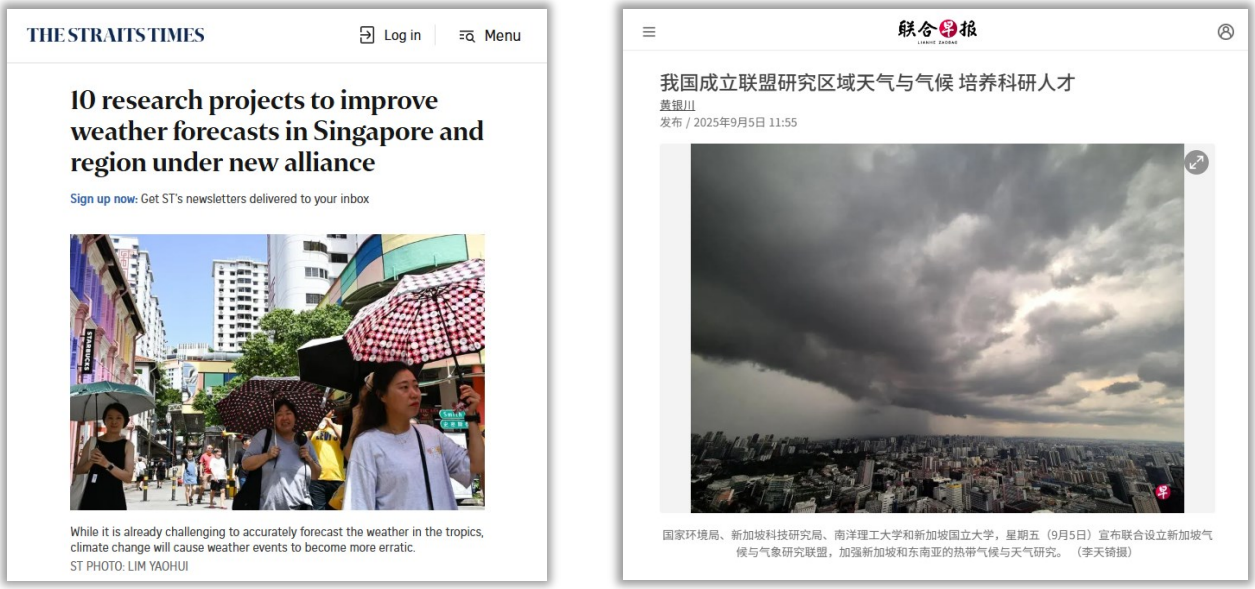
Dr Sandeep Sahany, Head of CCRS' Climate Projections and Extremes Branch, shared key findings from Singapore's Third National Climate Change Study (V3).

CCRS Senior Research Scientist Dr Jianjun Yu shared his work on extreme temperature and heat projections.

Participants of the CCRS-V3/CORDEX-SEA Downscaling Products and Applications Roadshow in Kuala Lumpur, Malaysia on 27–28 October 2025.

Media Highlights

The launch of the Climate and Weather Research Alliance Singapore (CAWRAS) in September 2025 was featured in various news outlets such as The Straits Times and Lianhe Zaobao, Singapore's Chinese newspaper. Visit https://www.straitstimes.com/singapore/environment/10-research-projects-to-improve-weather-forecasts-in-spore-region-under-new-alliance and https://www.zaobao.com.sg/realtime/singapore/story20250905-7464881 to learn more.



The launch of the Climate and Weather Research Alliance Singapore (CAWRAS) on 5 September 2026 was covered in The Straits Times (left) and Lianhe Zaobao (right).

In an interview with CNA, a Singapore-based English language Asian news network, CCRS Director Prof Dale Barker shared the problems that CAWRAS is looking to solve, and the immediate and long-term priorities of the alliance. Visit https://youtu.be/VjiY_gsdfLE to find out more.

CCRS Director Prof Dale Barker shared with CNA the priorities and function of the Climate and Weather Research Alliance Singapore.

Staff Spotlight

Congratulations!

Dr Aurel Moise
Deputy Director

Dr Aurel Moise, Deputy Director of CCRS' Department of Climate Research, has been appointed as Lead Author for 'Chapter 2: Vulnerabilities, Impacts and Risks' in the Intergovernmental Panel on Climate Change (IPCC) 7th Assessment Report (AR7) Working Group II.

Dr Moise's appointment recognises his expertise in climate science and significant contributions to understanding climate change impacts. At CCRS, he successfully led Singapore's Third National Climate Change Study (V3), whose comprehensive findings were released in January 2024, providing crucial climate projections for Singapore and the wider Southeast Asia region. He has also been spearheading regional outreach efforts to share V3 products across the region, strengthening climate resilience capabilities.

His involvement in this global assessment will help ensure the latest climate science knowledge, including insights from tropical and regional climate research, is accurately represented in this crucial report that serves as the foundation for climate policies worldwide. This appointment reflects CCRS' commitment to advancing climate science that informs decision-making at national, regional and global levels.

Dr Rajesh Kumar
Deputy Principal Research Scientist

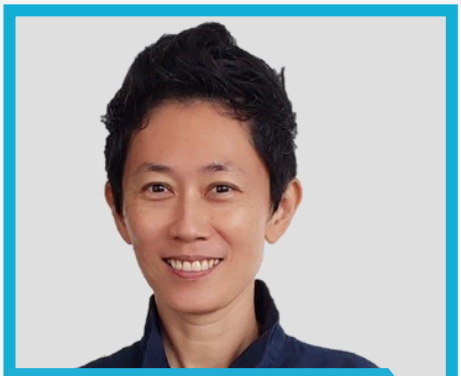
Dr Rajesh Kumar, CCRS Deputy Principal Research Scientist, has been appointed as a member of the World Meteorological Organization's Working Group on Coupled Modelling (WGCM) under the World Climate Research Programme (WCRP).

Dr Kumar's four-year appointment recognises his expertise in high-resolution coupled atmosphere-ocean-wave modelling, wave climate, and regional air-sea interactions. As part of this international scientific community, he will contribute to the development and evaluation of next-generation coupled climate and Earth system models, with a focus on key processes such as air-sea interactions, extreme events, and regional climate variability.

The WGCM plays a vital role in advancing global climate science by promoting coupled model development, coordinating model intercomparisons like CMIP[1], and supporting climate variability research. This appointment reflects CCRS' growing contributions to the international climate modelling community and will enhance our capability to improve understanding of Southeast Asia's climate system and develop more reliable regional climate projections.

[1] The Coupled Model Intercomparison Project Phase 6 (CMIP6), an international effort among the climate modelling community aimed at coordinating climate change projections

Welcome new CCRS staff!



Ipein Chua
Senior Assistant Director

I joined the Department of Research Masterplanning in August 2025 to contribute to building the Research, Innovation and Enterprise 2030 (RIE2030) research portfolio for weather and climate science, including the launch of the Climate and Weather Research Alliance Singapore (CAWRAS).

Currently I'm working on the Ops-Tech Roadmap (OTR) for RIE2030, which is a strategic plan outlining an organisation's growth trajectory and how it could leverage on technologies to achieve its operational goals over the short, medium to long term. The purpose is to link resources to objectives to develop R&D plans/ technology solutions that are fit-for-purpose and cost-effective. We can look forward to a few cross-agency OTR workshops in early 2026 that aim for strategic alignment in capability and systems development, especially in important cross-cutting areas. This will enable inter- and intra- agency stakeholders in policy, operation, Science and Technology, and supporting departments to plan cohesively and synergistically in weather and climate science research.

Adam Clayton
Deputy Principal Research Scientist

I joined CCRS in November 2025, following a 27-year career at the UK Met Office, where I focused mainly on developing variational data assimilation systems, and 5 years at the Korea Institute of Atmospheric Prediction Systems (KIAPS), as head of the Data Assimilation Techniques team.

At CCRS, I am leading the Data Assimilation and Ensembles branch, which is developing data assimilation and ensemble systems for next-generation SINGV models, for both operational weather forecasting and producing multi-decadal regional reanalyses. The systems will be based on the 'JEDI' data assimilation framework, which is developed and managed by the Joint Center for Satellite Data Assimilation (JCSDA), and will be developed in collaboration with both our broad range of international partners, and our local partners within CAWRAS.

Dr Kashyapa Athreyas
Research Scientist

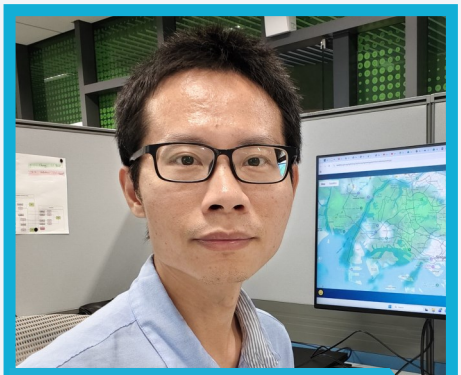
I am a part of the Data Assimilation and Ensembles branch under the Department of Weather Research in CCRS. My primary work will focus on development of next generation data assimilation system and reanalysis for Singapore. My research will include analysing the current data assimilation frameworks such as 'JEDI' and developing methods to integrate new data from space and ground-based systems relevant for Singapore.

Before joining CCRS, I was working in Satellite Research Centre in the Nanyang Technological University Singapore where my main role was to design and develop satellite systems including designing the mission for Singapore government-based satellite missions. My expertise lies in orbit design, algorithm development for control and optimisation. These skills can be applicable to data assimilation from fresh perspective.

Dr Chih-Chi Hu
Research Scientist

I joined the Data Assimilation and Ensemble Branch, Department of Weather Research in October 2025. My work at CCRS focuses on leveraging satellite observations and AI to enhance the weather forecasts for Singapore and Southeast Asia regions.

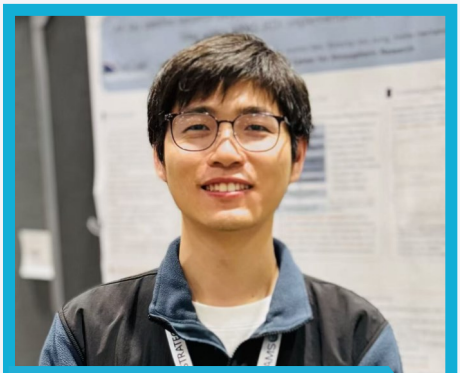
Before joining CCRS, my research focuses on advancing data assimilation methods for numerical weather prediction from both theoretical and practical perspectives, including the Particle Flow Filter and other non-Gaussian data assimilation methods. I am interested in using these techniques to best extract the information from observations to improve forecasting accuracy. Given the unique challenges that tropical weather presents for atmospheric data assimilation, I am excited to contribute my expertise to explore and develop new data assimilation techniques tailored for this region's complex meteorological conditions.



Dr Jianyu Liang
Research Scientist

I joined the Numerical Weather Prediction Branch in the Department of Weather Research at CCRS in November 2025. My work primarily focuses on radar quality control (QC), Quantitative Precipitation Estimation (QPE), and rainfall nowcasting.

Previously, I have simulated severe weather events, studied the impact of Saharan dust on tropical cyclone development, and applied data assimilation and machine learning techniques to atmospheric research. I am eager to leverage my expertise to improve radar QC, QPE, and rainfall nowcasting, helping to enhance weather prediction and decision-making for Singapore.



Dr Tao Sun
Research Scientist

I joined the Data Assimilation and Ensemble Branch of the Department of Weather Research in July 2025, contributing to the development of the data assimilation (DA) system for CCRS's next-generation numerical weather prediction framework, SINGV_NG.

My research focuses on multiscale data assimilation, ensemble-based DA techniques, and severe weather prediction. I have extensive experience in DA methodologies, particularly the assimilation of radar observations and satellite radiances within the Joint Effort for Data Assimilation Integration (JEDI), a universal DA framework designed to support multiple Earth system models. This expertise allows me to play an integral role in advancing the design and implementation of the JEDI-based DA system for SINGV_NG.

For other staff profiles, please visit http://ccrs.weather.gov.sg/our-people/.

Acknowledgements

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Danielle Su	—	Making Waves in Marine Modelling: CCRS Welcomes Its First Long-Term Visiting Scientist
Simon Peatman, Chen Schwartz	—	Boreal Summer Intra-Seasonal Oscillation (BSISO)

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- ASEAN Specialised Meteorological Centre (for the group photo of participants of the 25th ASEAN Climate Forum on page)
- Straits Times, CNA and Lianhe Zaobao (for the screenshots of news coverage on the Climate and Weather Research Alliance Singapore on page 19)

The CCRS Newsletter highlights CCRS' latest news, activities and progress. The Newsletter also shares latest climate/ weather science developments that are relevant to CCRS' mission. For feedback and enquiry, please email NEA_CCRS_Engage@nea.gov.sg or fill up the form at go.gov.sg/ccrs-newsletter-feedback.

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