PROCEEDINGS OF THE
APEC CLIMATE SYMPOSIUM 2022

ENHANCING APEC RESILIENCE THROUGH AI APPLICATIONS IN CLIMATE CHANGE ADAPTATION

CHA-AM, THAILAND / VIRTUAL

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This document summarizes the presentations and discussions from the APEC Climate Symposium (APCS) 2022, held in cooperation with the Thai Meteorological Department (TMD) on 15-16 September 2022.

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Overview

1. The APEC Climate Symposium 2022 was conducted on 15-16 September 2022 both online and offline in Cha-Am, Thailand. The meeting of the APCC Working Group was also held in conjunction with the event.

2. The event was attended by 246 participants from 31 economies – Australia, Brunei Darussalam, Chile, Chinese Taipei, Hong Kong – China, Indonesia, Japan, Malaysia, New Zealand, Papua New Guinea, Peru, Republic of Korea, Thailand, the Philippines, USA, Viet Nam, Samoa, Bangladesh, Brazil, Egypt, Ethiopia, India, Kiribati, Lao PDR, Mongolia, Nepal, Pakistan, Uganda, Spain, Switzerland, and Zambia. The participants included invited speakers and discussants, representatives from National Hydrological and Meteorological Services, government officials, private sectors, non-governmental agencies, and academia. Experts from a diverse range of backgrounds, including climatology, disaster risk management, conservation, AI technology and international development were invited to discuss ways to enhance APEC resilience through AI applications in climate change adaptation. A complete list of participants can be found in Annex I.

Executive Summary

3. The APEC Climate Symposium 2022, which focused on "Enhancing APEC resilience through AI applications in climate change adaptation," aimed to benefit APEC member economies to gain the capacity and knowledge necessary for applying AI technologies in climate change adaptation. In the first session "Tackling climate change with AI," experts shared their expertise on how AI technologies can help the climate change adaptation and discussed key considerations in utilizing AI technologies in tackling climate change. The second session "Application of AI towards the resilient APEC," focused on the case studies on applying Ai technologies to climate-related sectors including weather prediction, disaster monitoring using satellite through AI, and conservation. Also, challenges, opportunities, efforts amongst stakeholders on utilizing AI technologies towards resilient APEC were shared. Experts brought together their varied experience and insights on how emerging economies can better adopt AI technologies in climate change and overcome critical environmental challenges. Through the discussion session, experts and participants discussed and made recommendations on the use of AI technologies in tackling climate change as well as application of AI technologies to various climate-related fields such as climate prediction, disaster risk reduction, agriculture, biodiversity and so on. With the knowledge and experience shared by the experts, participants increased their understanding on the use of AI technologies in tackling climate change.

Opening Ceremony

4. The APEC Climate Symposium 2022 opened the event on Thursday, 15 September 2022. The Opening Ceremony began at 10:30AM (KST) with Ms. Sangwon Moon, the head of the External Affairs Department at the APEC Climate Center (APCC), opening the ceremony and welcoming everyone to the event. She also thanked the co-host, the Thai Meteorological Department (TMD) for their great efforts putting together the event. Ms. Moon then introduced Mr. Chaiwut Thanakamanusorn, the Minister of Digital Economy Society of Thailand for his Opening Remarks. Mr. Thanakamanusorn started his Remarks by sending his appreciation to the APEC Climate Center and participants and spoke about the severity of climate change impact in the APEC region and highlighted the importance of translating AI technologies into protective measures against disaster risks and climate crisis for enhancing the resilience of the region. The session was closed with both virtual and on-site group photo of participants.

Session I: Tackling climate change with AI

5. Session I, chaired by Prof. Dale Durran, professor of the Department of Atmospheric Science at University of Washington in the USA, began at 10:40AM(KST) on 15 September 2022. This session shared status of AI in climate change including opportunities, challenges, and recommendations and NVDIA's AI technologies. In addition, current level of credibility and reliability of AI technologies in climate change adaptation was discussed. Experts also shared their view on weather AI technologies are advanced enough to be applied in various sectors such as climate prediction, biodiversity, and so on. Advantages and disadvantages, challenges, and barriers in application of AI technologies were also explored. The session was finalized with considerations in developing and applying AI technologies in tackling climate change and ways forward were suggested.

6. **AI and Climate Change: Opportunities, challenges, and recommendations - Prof. David Rolnick (Assistant Professor, School of Computer Science, McGill University)**

   Prof. David Rolnick started his presentation by talking through at a very high level what AI is as there are so many different words loading around. AI means a lot of things, but it generally means any computer algorithm that makes predictions, recommendations, or decisions based on a defined set of objectives, according to the definition from the OECD AI Principles. Within AI, there are several different techniques, different kinds of computer algorithms. Machine Learning which refers AI algorithms that infer patterns from data. Its techniques are kind of AI that have become extremely popular, effective in recent years. Within Machine Learning, people might have heard words like Deep Learning or Neural Networks, these are kinds of Machine Learning that is called to become extremely popular recently. There are many kinds of Machine Learning and many kinds of AI which are extremely affective and widely used. So, AI is not something that is extremely advancing necessarily or even remotely intelligent. There is a huge gap, which I think everyone should remember, between Artificial Intelligence and what we can really see about as intelligence in a human sense. AI is nowhere near humans. But it does have its strengths. For instance, performing simple tasks quickly and automatically. Various kinds of tasks, everything from labelling images to, for example, making a prediction on the basis of past data to what's going to happen in the future, tasks that human can do but we take a long time, but a computer can now scale up. Finding subtle patterns in large datasets is another example. Machine learning algorithms infer patterns from data and take a large amount of data to work out how to decide based upon the data. They can find subtle patterns that a human might not have a patience for within a large dataset. Also, optimizing complicated systems where there are many nubs that can be turned to control something quite complicated. He then explained the weakness of machine learning and AI algorithms. AI algorithms are very sensitive to bad or biased data. If people have trained or developed the algorithm base on a large body of data, it will be very sensitive to what is in the data. So, if the data is bad or if it has a bias in it, which might be in serious bias introduced by the human who created that data, then the AI can perpetuate those inaccuracies or biases and can make them seen like objective truth whereas an AI is only as good as the data that was used to develop it. And sometimes, it's worst. In addition, AI algorithms do not fundamentally have a common sense. They do at best what they were told to do but they do not know the scope of human knowledge outside of the data that they were given. And they are not able to perform with common sense or intuition about the broader context that the world around them. Also, , they cannot explain, generally speaking, why their answers are true. This is particular the case of Machine Learning algorithms. It's not the case for all the AI algorithms. But Machine Learning algorithms, in particular, are very weak when it comes to explaining how they made a decision. They infer patterns from data and given new data that are able to predict and answer. But that prediction is out of thin air, it does not necessarily come with any reasoning about why the answer is true.

He then dealt with matters on how AI and Machine Learning can be relevant to the context of climate action based on a report called 'Tackling climate change with Machine Learning', which was published this year in ACM Computing Surveys, and this provides an overview of the many ways in which the AI and Machine Learning can be relevant in the fight against climate change, both climate change mitigation and adaptation. He shared five key opportunities for AI in tackling climate change: i) distilling raw data into actionable information, ii) improving operational efficiency, iii) forecasting, iv) speeding up time-intensive simulations, and v) accelerating scientific discovery. In distilling raw data, the main role for AI is automatic labeling, for instance, satellite images or textual data. Examples includes mapping deforestation and carbon stock, gathering data on building footprints/heights, evaluation coastal flood risk, and parsing corporate disclosures for climate-relevant information. In improving operational efficiency, the main role for AI is optimization and control. The examples include managing the electric grid, operating heating/cooling systems efficiently, and optimizing rail and multimodal transportation. In forecasting, the main role for AI is predictions from time-series data. Examples include "nowcasting" for solar/wind power, forecasting electricity demand, and predicting crop yield from satellite images. In speeding up simulations, the main role for AI is to approximate the output of time-intensive simulations. Examples include higher resolution predictions from climate models and simulating portions of car aerodynamics. In accelerating scientific discovery, the main role for AI is to suggest which experiments to try. Examples include identifying candidate materials for batteries, photovoltaics, and energy-related catalysts and improving charging protocols for electric vehicle batteries.

Then, he shared considerations for AI. AI is not a silver bullet and is also relevant sometimes. High-impact applications are not always flashy. Even when working with data, sometimes simple methods work. AI can be used to get the wrong answer fast and it is not a substitute for thinking. AI is intrinsically neither good nor bad for climate change and it is how it is being used. Finally, the partnership between stakeholders with complementary expertise is crucial in the successful application of AI in climate change.

He also suggested some recommendations for government action for climate change and AI. In terms of data and digital infrastructure, it is necessary to ensure the availability of data and infrastructure on which AI algorithms depend. For this, considerations are as follows; i) relevant data may not exist and are unequally distributed, ii) incentives and standards for data sharing are nascent, iii) data quality is often low and standards are lacking, iv) computing infrastructure is often a bottleneck. In this regard, he recommends that establishment of data task forces and platforms for data collection and sharing in climate-critical sectors. Also, it is necessary to support the availability of compute and data storage for researcher, civil society and smaller scale enterprises. In the perspective of research and innovation funding, it is necessary to ensure and direct funding for research and innovation in relevant technologies. For this, considerations are as follows; i) AI funding is often methodological and climate funding is often sector-specific, ii) there is a potential neglect of less flashy low-hanging fruit; and iii) there is imbalanced funding geographically and priorities are often driven by Global North. In this regard, he recommends that ensuring funding on AI-for-climate project needs to be impact-driven, not tech-driven also considering pathways to deployment as well as accommodating AI where relevant within wider climate grand challenges. In terms of deployment and systems integration, it is necessary to ensure promising research and development is impactfully deployed and scaled. For this, considerations are as follows; i) reliability or security guarantees are needed in some sectors, ii) organizational culture & legacy infrastructure may slow adoption; and iii) some opportunities fall outside traditional incentive structures. In this regard, he suggested development of cross-sectoral innovation centers to incubate projects, facilitate collaborations, and hone scaling models. Development and maintaining non-commercial public interest applications was suggested as well. In the view of capacity building, it is necessary to support the growth of literacy, talent, and tools needed for AI-for-climate projects to be deployed responsibly, effectively, and equitably. For this, considerations include as follows: i) capacity is needed across wide range of entities/geographies, private sector, civil society, etc.; ii) there is a need for cross-functional and cross-sectoral coordination; and iii) there is a risk of system capture or potentially it requires high costs. In this regard, he suggested implementation of AI literacy and upskilling programs for governments, climate-relevant industries, and civil society. Also, funding or facilitating secondment programs for AI experts within climate-relevant sectors as well as the creating of trusted AI-for-climate solutions providers and auditors was suggested.

7. Earth-2: Digital Twins for Climate Change Prediction, Mitigation and Adaptation - Dr. Karthik Kashinath (Principal scientist and engineer, HPC/AI, NVIDIA corporation)

Dr. Karthik Kashinath introduced NVIDIA's Earth-2 initiative in talking about how Machine Learning changes scientific computing and weather and climate change impacts. Earth-2 aims to building digital twins for weather and climate. Dramatic and extreme weather have impacts all around the globe. Wildfires, extreme flooding, droughts, extreme precipitation events, agricultural impacts are increasing its frequency and intensity and those impacts are not just on humans but also on the natural ecosystems and the entire planet. Thus, we urgently need better tools including wildfire prevention, water management, crop forecasting and a host of other very important applications that have critical consequences for society and natural ecosystems to prepare for the climate change. Many climate scientists and weather modelers have worked on weather and climate modeling for a long time, but high-resolution climate prediction faces a serious computational challenge, and it is due to the computational challenges as it requires more computing than the current computational requirements. Also, interacting with high-resolution climate data is extremely difficult and this has to do with the fact that we have petabyte climate data available today and we cannot compute a very short set of km-scale simulations and they are memory-intensive which occupies a large amount of storage. Thus, we need systems that government policy makers, decision-makers, planners can look at climate data and have them think about questions that require information systems that allow interactivity which currently does not exist for high-resolution climate data. With the advances in computing and Machine Learning, we began to see many million-X speedups and accelerated computing over time. The Earth-2 initiative began as a vision of a highly interactive climate information system for serving society with next-generation climate prediction. Its mission is to be able to interact with climate predictions at low latency to be able to get answers to questions much faster than we can today. Another mission is to achieve next-generation weather and climate predictions using a combination of hybrid physics and Machine Learning as well HPC. Earth-2 is a very much collaborative initiative with international climate science society. A digital twin is essentially digital replica of a physical system that's faithful to the physics of that system, physics, chemistry, biology, all the science to that system. And it is also a system that is continuously calibrating itself as new data comes in, something that is updated constantly and can predict the future of that system with high accuracy. The digital twin can predict the evolution of the oceans and the atmosphere over a long period of time and can be coupled to a weather digital twin which is initialized using climate conditions and can run a very large ensembles of simulations for predicting extreme weather. It can be harvested and fed into a power plant digital twin that responses to changes in weather as well as an electrical grid model and electrical grid digital twin that can tell you about the vulnerability in the electrical grid due to weather fluctuations in extreme weather events. He then gave an example of what Machine Learning is capable today in terms of the complex chaotic turbulence system, so called 'FourCastNet.' FourCastNet is a name of the model that is based on the technologies that was used to developed it which is the Fourier Neural Operator so it stands for a Fourier Forecasting Neural Network. It is a data-driven digital twin of the weather. Some key features are that it is a global model and it's used for medium-range weather forecasting. They are trying to push the limits to potentially sub-seasonal to seasonal scales. It is also based on a Full-Model emulations, so it is a full emulation of the atmospheric phenomena. The key features of FourCastNet are that it is about 45,000 times less computing intensive and about 12,000 times less energy intensive than traditional remarkable weather simulations. FourCastNet is the highest resolution that we have currently today for data-driven remarkable weather prediction and about a million pixels. So, we were able to ingest this very large data set because of a combination of advances in both Machine Learning and Computing. It is a physics-based approach that is looking for grid-free, high-resolution machine-learned solutions for a complex system such as the earth's atmosphere that are governed by partial differential equations. The main advantage of having this extremely large ensembles is that we can then characterize the long tails of the distribution much more accurately with higher confidence and then capture these very rare extreme events with greater confidence. For climate science, given that FourCastNet is extremely good at weather prediction, it is suggested that combining this with climate simulations and basically using as an interpolator with checkpoints of very high-resolution numerical climate simulations. He finalized his talk by saying that climate modeling and weather forecasting are extremely computational and extensive and we can provide million X speedups by combining accelerated Computing and Machine Learning, and AI-powered digital twins are promising actionable results in actionable time. And Earth-2 is combining all these together to address challenges of our time.

8. Questions & Answers

There was a question from the audience on whether Earth-2 emulated the physical model with an AI model just to observe the dataset to simulate the model and Dr. Kashinath answered that the FourCastNet is purely data-driven and it is trained on reanalysis data which combines numerical simulation dataset with observations. The result shown in the

Omniverse from climate simulations from CESM at 25km, so Earth-2 uses both physical and AI models.

9. Discussion

For the first discussion topic, experts addressed the current level of credibility and reliability of AI technologies for climate change adaptation. Prof. Rolnick responded that some of the challenges that AI can have overall are in terms of robustness under data regimes like if the data were to change or if there were something that happened that the AI had not seen before, or if you need to understand why the AI is making a certain decision and that is another weakness that AI can have or you need to quantify the uncertainty in a prediction. The AI community is working on this area, but it is important to remember that most of these applications, the AI technologies are ready in some forms, and if we give them relatively straight forward and well-defined problems, they answer right most of the time. He also mentioned that the examples of applications he gave during his talk are being deployed now and in 10 years down the road, we will have better algorithms and they will be able to do more. He also added that it is important to remember the matrix or evaluating those tools really depend upon the situation. Thus, it is fundamentally important to develop AI tools together with the stakeholders who will be using those tools. Because what kind of reliability is needed really depends upon the setting. Dr. Kashinath also gave his response focusing on the two domains of weather and climate prediction. He mentioned that the data-driven weather prediction is starting to get very close to the numerical prediction. Thus, the accuracy, the skill and the performance of the models is very good. Yet, the credibility and reliability of these models are still underdeveloped partly because it is a field that is very driven by the science of the physics of a system. In order to make weather prediction reliable and creditable for forecaster and meteorologist, they would like to understand a little more about how these predictions were made and if it has the features that we care about such as actual atmosphere and the ocean. In terms of climate prediction, it is very early stage for AI to be reliably and credibly predict climate change which is several decades ahead as climate is changing and its distribution is not stationary. Thus, there are a lot of work to be done to build credibility and reliability in the climate change model.

The second topic of the discussion was on whether the technologies are advanced enough to be applied in various sectors such as climate prediction and biodiversity, etc. Prof. Rolnick began his response by mentioning that AI tools cannot solve every problem, but rather we should think of them in solving narrow well-defined problems. AI tools are not yet advanced enough to recommend policies, simulate the whole earth's functioning or understanding how people behave. In terms of small well-defined problems, AI is advanced enough through.

The discussion was followed by the next topic of advantages, challenges, and barriers in the application of AI technologies. Prof. Rolnick mentioned that the biggest challenge is technical solutionism thinking that fancy technologies are going to solve all our problems. We should use those technologies where relevant. For instance, in flood response, AI can be very impactful currently. Some of the barriers from a practical perspective include a lack of data, computational infrastructure, and particularly inequitable distribution and geographically of data and digital infrastructure. Barriers in capacity, especially knowledge of relevant AI tools within both private and public sector, lack of international cooperation on various critical issues were also mentioned. Dr. Kashinath also added that as AI is a very complex field and it requires a fair amount of time to understand how these tools work, what their limitations are, what their advantages are. Thus, the collaboration and bringing together expertise are critical for the success of AI application. For instance, weather and climate prediction field needs to bring together experts in the physical science, AI, computing, impacts, and so on so all those experts need to be working together to develop these solutions.

The discussion session was finalized with sharing thoughts for developing and applying AI technologies in tackling climate change and a way forward. Prof. Rolnick summarized his thoughts first. n terms of distilling data into usable information forecasting and prediction in optimization of complicating systems, operational complicated systems to be more efficient and accelerating scientific discovery and speeding up simulations. And I think it's important to recognize that there are a multitude of medium impact problems. There is no single way that AI is solving climate change, or no single application of AI that is the way that we should be pushing forward. There are a lot of ways to integrate AI into existing climate strategies to make them somewhat better. And so, one should struggle against the impulse to think that AI is blur that the way forward is to use AI in this kind of application or this kind of application, because there are a lot of different applications and no one of them is the answer in any way. we should be thinking in terms of building knowledge and capacity to use these kinds of technological tools very critically, where they are relevant. In addition, he mentioned that AI is a multi purpose tool and there are many ways that AI is being used in ways that are detrimental to climate action. So fundamentally, aligning AI with climate action requires more than just adding good applications of AI on top of business as usual. Dr. Kashinath added his point saying that developing highly interdisciplinary teams and combining the expertise that we have in academia with industry and government resources are very important. Also, he highlighted the importance of funding which funds high-risk, high-reward opportunities at the intersection of science and AI and see if there can be explorations of potentially radical approaches to address some of the most pressing challenges for our time, climate change.

Session II: Application of AI towards the resilient APEC

10. The second session of Symposium commenced at 10:30AM KST on the 16th September 2022. Session II shared case studies where AI technologies are applied in climate-related sectors including weather prediction, drought monitoring and conservation. Also, experts discussed roles of government, international organizations, and private sectors on how best to transfer the AI technologies and promote international cooperation. Also, discussants addressed how to empower emerging economies in the APEC region for better adopting AI technologies for climate change adaptation. Needs from the emerging economies in adopting and applying AI technologies for climate change adaptation were shared and recommendations for the effective use of AI technologies in climate change adaptation and mitigation to enhance resilient APEC were made. The Session was chaired by Prof. Faridah Othman, Professor of Department of Civil Engineering at University of Malaya.

11. Weather Prediction by using Support Vector Machine - Dr. Wattana Kanbua (Director, Meteorological Development Division, Thai Meteorological Department)

Dr. Wattana Kanbua gave a presentation on weather prediction by using support vector machine. He first began his presentation by describing natural disaster in Thailand. In Thailand, the floods normally occur in rainy season which is from mid-May to the mid-October and people are worried about the climate change as they affect their land use such as roads and construction of buildings while obstruct the flow of the water. Next, he briefly explained the precipitation and temperature as they are two very important parameters in climate. Forecasting and monitoring precipitation and air temperature are fundamental issues for the society and various sectors of the economy. We can plan the activities of the community and be prepared to deal with droughts, flood and cold weather. At the Thai Meteorological Department (TMD), they are currently trying to explore new ways of forecasting such as artificial intelligence to forecast the weather. The AI and data science technology, specifically machine learning, bridge the gap between numerical prediction model and real-time guidance by improving accuracy. AI technique also extract otherwise unavailable information from forecast models by infusing model output with observation to provide additional decision support for forecasters and users. Machine learning, based on statistical methods, has been widely used to improve the accuracy of the prediction of air temperature and precipitation. AI is the innovation that creates change leads to the development of the technology of the future. But AI' s analytical thinking process consists of sub-components such as machine learning and deep learning, in which both elements act as the brain of the AI. It is an important part of learning, thinking, analyzing, and processing. And many methods are widely used including linear and non-linear regression, canonical correlation, artificial neural network, relevance vector machine and support vector machine.

He then explained how he used the Support Vector Machine (SVM) to improve his model. SVC is a machine learning that is supervised learning by finding hyperplane between each data type with the largest margin from the data location. The main objective of SVM is to find the optimal hyperplane which linearly separates the data points in two components or classes by maximizing the margin or equivalently minimizing the magnitude of weighted vector. He shared his study results using SVM in the forecast of precipitation. In his study, he collected time series climate dataset from the weather stations in Thailand and used them for training them with SVM method. The training set was composed of data from 2011 to 2019 and the test set used for the model validation of prediction was composed of data from 1 March 2020 to 31 December 2021. According to his study, the Mean Absolute Error(MAE) ranges from 0.72 to 2.08 and the Mean Absolute Percentage Error(MAPE) ranges from 3.18 to 10.07 for minimum temperature whereas MAE ranges from 1.92 to 3.88 and MAPE ranges from 6.27 to 10.26 for maximum temperature. In contrast, MAE ranges from 6.98 to 18.64 for precipitation. In conclusion, he mentioned that SVM model can give good prediction on air temperature and the prediction on precipitation is fairly good, but we still need to use existing approach along with the AI techniques as AI techniques require a plenty of data to create good prediction model. He finalized his talk by saying that applying AI techniques along with a physical understanding of the environment can significantly improve the prediction skill for multiple types of high-impact precipitation from tropical cyclones.

12. Disaster Monitoring using Satellite through AI - Prof. Seonyoung Park (Assistant Professor, Dept. of Applied Artificial Intelligence, Seoul National University of Science and Technology)

Prof. Seonyoung Park gave her presentation on disaster monitoring using satellite through AI, focusing on drought. She began her presentation by defining two types of AI, strong AI and weak AI. The weak AI has one purpose only while strong AI controls a number of purposes like human being and that is why many scientists and researchers try to develop strong AI. She then shared her research outcomes. Drought triggered by a deficit of precipitation, is influenced by various environmental factors such as temperature and evapotranspiration and causes water shortage and crop failure problems. In her study, multi-sensor data are used to assess meteorological and agricultural drought. Machine learning approaches are used also to examine the importance of drought factors. Drought indicators are developed to monitor meteorological and agricultural drought and satellite-based drought monitoring is assessed for different climate regions. The relationship between sixteen remote sensing-based drought factors and in-situ reference data was modeled through three machine learning approaches: random forecast, boosted regression trees, and Cubist, which have proved to be robust and flexible in many regression tasks. Results showed that random forest produced the best performance for SPI prediction among the three approached. Land surface-related drought factors, e.g., Land Surface Temperature (LST) and Evapotranspiration (ET) showed higher relative importance for short-term meteorological drought while vegetation-related drought factors, e.g., Normalized Difference Vegetation Index (NVDI) and Normalized Multi-band Drought Index (NMDI) showed higher relative importance for long-term meteorological drought by random forest. Six drought factors were selected based on the relative importance by their category to develop drought indicators that represent meteorological and agricultural drought by using the relative importance as weights. While TRMM showed higher relative importance for meteorological drought, LST and NDVI showed higher relative importance for agricultural drought in the arid and humid region, respectively. She also mentioned some limitations of her study including that crop yield samples were limited due to the study area selection and as the current thresholds to determine drought conditions are arbitrary, specific standards and guidelines on thresholds should follow. Finally, drought distribution maps were produced using the drought indicators and compared with the U.S. Drought Monitor (USDM) maps, which showed a strong visual agreement. Then, she shared another study on a very short-term prediction of drought using remote sending data and MJO index through random forest over East Asia. Although many drought monitoring and warning systems have been developed in recent decades, the short-term prediction of droughts (within 10 days) is still challenging. In this study she has developed drought prediction models for a short-period of time (one pentad) using remote-sensing data and climate variability indices over East Asia through random forest machine learning. Satellite-based drought indices were calculated using the European Space Agency (ESA) Climate Change Initiative (CCI) soil moisture, Tropical Rainfall Measuring Mission (TRMM) precipitation, Moderate Resolution Imaging Spectroradiometer (MODIS) land surface temperature (LST), and normalized difference vegetation index (NDVI). The real-time multivariate (RMM) Madden–Julian oscillation (MJO) indices were used because the MJO is a short timescale climate variability and has important implications for droughts in East Asia. The validation results showed that those drought prediction models with the MJO variables outperformed the original models without the MJO variables. The predicted drought index maps showed similar spatial distribution to actual drought index maps. In particular, the MJO-based models captured sudden changes in drought conditions well, from normal/wet to dry or dry to normal/wet. Since the developed models can produce drought prediction maps at high resolution (5 km) for a very short timescale (one pentad), she mentioned that they are expected to provide decision makers with more accurate information on rapidly changing drought conditions. Also, she added that although RMM MJO indices contributed to enhancement of drought prediction, there is still a limitation. The performances of drought prediction models were saturated to 0.7 in correlation in three drought indices. Therefore, she suggested other factors including interannual climate variability and local characteristics including topography and land use be investigated to develop more accurate prediction model in the future.

13. AI and Resilience from a Conservation Perspective - Dr. Dave Thau (Global data and technology lead scientist, Global Science, World Wildlife Fund)

Dr. Dave Thau from the World Wildlife Fund (WWF) opened his presentation by introducing WWF. The mission of WWF is to conserve nature and reduce the most pressing threats to the diversity of life on Earth. They work in 100 different economies around the world and have offices in many places and work mainly on the conservation. Six main areas of focus include forests, freshwater, oceans, wildlife conservation, climate and food. The world is facing with three challenges: climate change, biodiversity loss, and food insecurity. In terms of climate change, the temperature anomalies are increasing with the amount of CO_2 in the atmosphere and the impact that is having around the world is notable. According to German watch that publishes a global climate risk index, it lists the top 10 economies with the highest risk. Many of them are in Asia and the Intergovernmental Panel on Climate Change recently released the report on vulnerability to climate change. In terms of biodiversity, the challenge is that extinctions are increasing, and the population size of different species is decreasing, and it is affecting different species more than others. But we know that biodiversity is decreasing around the world, and this is exacerbated by climate change. And one of the tools that we use to help battle this is artificial intelligence. Then, he continued his presentation by showcasing two projects that WWF is using artificial intelligence for conservation to help adapt to climate change. The first project he introduced was a project called 'forest foresight' which was developed with the WWF Netherlands and is currently being applied in many places including Indonesia. This is an early warning system to predict deforestation. The deforestation is a big issue around the world, many tons of CO2 are released because of deforestation. Large swaps of forest or loss that has impact on biodiversity and many people are impacted by it. More than 1.6 billion people depend on forests, and the estimates of the impact of forest degradation and destruction are about 20%, 17% of a global carbon emission come from degradation. And much of the world's biodiversity, different kinds of wildlife and plant life are living in forest. The 'forest foresight' tries to predict where forest loss will happen so that government or whoever is managing the land can act in time to help save the deforestation off. It has a set of tools that use machine learning to predict where forest loss will happen and them that creates alerts better than prioritized so that people using the system can identify the predictions that are most important to them. Then, there are tools to help them identify where they have investigated and measure the impact of their investigation, and then that information goes back into train the machine learning model. They also use satellite data, and it uses algorithm called XG boost or Extreme Gradient boosting. It t rains predictive model, which is then displayed to the forest managers to determine where they should investigate on the ground. So, they can visualize where the predictions are, and they can prioritize based on what they think is important. When they identify an area that they want to investigate, they can use the tools to say where they are investigating and then follow up and take notes for what they have seen in the investigation. The predictions from the system turned out to be true. The key to this system is to work with people on the ground who are actually managing the forest, including government, forest managers and other stakeholders. In order to do so, it is necessary to set up a team to coordinate stakeholders and organize training as well as regular meetings for each phase and finally align governance scheme and set up steering committee, user board etc.

Then, he gave another example on how WWF uses motion detecting cameras to help with climate resilience, so-called 'Wildlife Insight.' The challenges in wildlife conservations are : i) camera traps can provide the necessary data about wildlife population; ii) millions of images are taken around the world every day, and iii) yet most of these images and data are not effectively shared or analyzed, leaving valuable insights just out of our reach. According to his presentation, the AI models in Wildlife Insights catch 79% of blank images with an error rate of less than 12% and for up to 100 species Wildlife Insights AI models are able to catch between 80% and 98.6% correctly. While human experts can label between 300-1000 images per hour, a single machine can identify 18,000 images per hour, and when we parallelize across hundreds or thousands of GPUs, AI can save biologists a lot of time. He finalized his talk by sharing some challenges in the application of AI for conservation. Firstly, in conservation, measuring the quality of life of people is very challenging and there are issues around data privacy that are not true in other kinds of artificial intelligence. In addition, the biggest challenge is impact monitoring knowing when or what we are doing has an impact and what the impact is.

14. Discussion

The discussion session began with the first question, focusing on 'Role of government, international organizations, and private sectors on how best to transfer the AI technologies and promote international cooperation.'

Ms. Kelly Forbes, Executive Director of AI Asia Pacific Institute began answer the question by explaining that the success of AI in society will be directly correlated to the ability of humans to adopt and trust its capabilities. The downside of this powerful technology is that it has a fear and hype which in turn reduces its ability to be effective in sectors that matter like health, education, energy, and agriculture. Government, international organizations, and private sectors have a role to ease the adoption and address the right elements from a policy, scientific, engineering, and human aspect. AI is international. It crosses borders and therefore we can only appropriately address these elements through international cooperation. She especially shed a light on the importance of trust. Trust is built from the understanding of how solutions function and the acceptance that it serves a societal need, meaning a positive relationship between humans and technology. If we trust GRAB/UBER already with our travel data learnings to help transport us from A to B, we could apply the same trust paradigms to share learnings in addressing climate change to improve the output of our agricultural fields for example.

After that, she also added that we must amplify comprehensive information, education, and communications campaigns to promote Trustworthy AI. That means encouraging a holistic engagement strategy which fosters community engagement that can be pivotal to promote principles and values that support or promote the development of trustworthy AI. It can boost public confidence and allay fears or misconceptions on the implications of AI. At the same time, we must proceed and continue to build on public confidence and developing human capacity needs to be at the forefront these issues.

Prof. Seree Supratid, Director of climate change and disaster center at Rangsit University shared his view highlighting the role of science in policy making. He mentioned that AI applications are growing but slower compared to other business sectors, especially in the government and most of AI users are from the academia. One of the main reasons is limited data availability. In order to promote international cooperation on AI application, he said it requires various international workshops to allow users to learn the practical use of AI application.

Dr. Sanjay Srivastava, Chief of disaster risk reduction of UNESCAP, addressed that It's important to build credible narrative on the value that Artificial intelligence (AI) can add to a range of disaster risk reduction activities. For example, how AI improves risk analytics such as dynamic and multi-hazard risk assessment, forecasting of extreme events, real time detection of events, its potential impacts, early warning to early action through the provision of situational awareness and decision support. The recognition of the fact AI enhances the overall operational capacities to manage disaster risk and its complex, compound and cascading impacts determines the role of the governments. Then, he gave an example of what difference AI can make. building on the work on flood forecasting in previous years, Google extended, just in time for 2020/2021 monsoon season, its AI based next generation flood forecasting work in India and Bangladesh. Using Google AI technology to optimize the targeting of every alert the two governments send out; it is estimated that over 200 million people across an area spanning more than 250,000 square kilometers will have benefitted from the early warning system. The new forecasting model allows to double the lead time of many of the alerts in the past providing more notice to governments and giving tens of millions of people an extra day or so to prepare. It also provides people with information about flood depth: when and how much flood waters are likely to rise. The information is provided through mobile phone in different formats, so that people can both read their alerts and see them presented visually and in their local languages.

The second topic of discussion, 'how to empower emerging economies in the APEC region for better adopting AI technologies for climate change adaptation and overcoming critical environmental challenges was followed.

Ms. Kelly Forbes mentioned that the future of power will transit from a predominantly fuel based power (e.g. oil, gas, water, etc.) to a mainly technology based power. The driver for this change is that no matter how energy intensive the fuel, the fundamental principles of centralized power systems are highly inefficient. Thus, Artificial Intelligence has a critical role to play in this shift to facilitate keeping the lights on and the price affordable, while enabling and accelerating the distributed network, promise of a targeted NetZero emissions and sustainable power. Autonomous Power Systems are our best bet in stabilizing demand, emissions, affordability, and supply. This is where Artificial Intelligence comes in. Not only to be able predict potential volatility to the entire system but also to better identify efficiency gains through optimization of generation, management of grids, or sharing of power is a problem best solved by learning algorithms. For those of us who know the strengths of data and learning technologies, we very well see a world with automation of generation and grid operations as the best possible solution to keep the cost of KWH down and the losses of energy as well as the resulting emissions to the minimum. Artificial Intelligence will help drive sustainability in the future much better than any individual fuel source can and the application of this technology is one that most power companies are just not ready for.

Prof. Seree Supratid added that emerging economies need guidelines and code of conduct in terms of AI applications as they are at the very early stage of applying AI technologies in various fields, especially in forecasting. Most of SMEs are behind the advancement of technology and so they need budget and technical support from the government. Also, project-based demonstration for the farmers who are working in the field of agriculture on how they can use AI technologies to enhance their productivity will be helpful.

Dr. Sanjay Srivastava explained the simplified AI lifecycle for disaster risk management. The Ai is making a difference for disaster risk management and that begins with data collection. In data collection, ones should consider data custodianship, curation, preparation, annotation, validation, ethics, privacy, ownership, and open source. Data policies and standardization of regulations play a very important role as well. Next one is model development. In model development, ones should consider handing of missing values in training data, problem formulation, selection of machine learning method, performance metrics and trustworthiness. The last one is model deployment. For this part, opportunities include real-time detection systems for alerts and early warning system, forecast and hazard mapping systems, and situational awareness and decision support systems. Then he gave an example of UNESCAP/WMO Typhoon Committee which has taken up several initiatives towards adopting AI technologies for forecasting the impacts of tropical cyclones on communities, economies and environment. He added that such intergovernmental platforms can help in empowering economies in the APEC region for scaling up the adoption of AI in Disaster Risk Reduction.

The next discussion topic was 'needs from the emerging economies in adopting and applying AI technologies for climate change adaptation.'

Ms. Kelly Forbes responded to the discussion topic by saying that the challenge ahead is significant, and it cannot be done without learning technologies. The ability to process vast amount of data in an instant and the discipline to build the right signals across the system to anticipate, understand and prescribe actions will be a must have to operate an energy business. Emerging economies need a better framework for the caption of data, and they need adequate to regulation to foster data, enabling them to efficiently fight against climate change. That data can then be used to monitor specific sectors. We need to see better policies facilitating hybrid systems, such as the use of batteries. On these learnings and going back to the importance of this. challenges and practices can be exchanged through a robust international cooperation structure.

Prof. Seree Supratid also added his point saying that they face constrains of budget, human recourse, development, and knowledge to transfer the AI technologies; thus, he highlighted

an importance of holding workshops to facilitate the learning and application of AI technologies in the field of agriculture and water management, especially in Thailand.
Dr. Sanjay Srivastava spotlighted one point as an example which can be very critical in disaster risk management. A project of NASA known as the Shuttle Radar Topography Mission(SRTM) is used worldwide by researcher working on coastal resilience. Analysts have relied on data sensed from Earth's orbit through SRTM but it has been found to over-estimate elevation by around two meters and correspondingly to dramatically under-estimate inundation. Now coastal digital elevation models (DEM) use AI/machine learning to produce a more accurate dataset, particularly for densely populated areas where people and structures are at greatest threat from rising sea levels. He mentioned that through this type of AI, economies can empower or use them to scale up adoption of the newly developed technologies.

The last discussion topic was 'recommendations for the effective use of AI technologies in climate change adaptation and mitigation to enhance resilient APEC.'

Ms. Forbes highlighted the importance of focusing on a sectoral and targeted approach. Economies have identified priority sectors where AI can have the most significant impact with a relatively short period of implementation. Such trends are dictated mainly by socio-economic challenges unique to each economy as well as by the nature of AI which is oriented towards scoping, testing, prototyping and scaling. In Japan, for example, we have emissions monitoring on fleet level, and other applications have been successful. Satellite images have also been successfully deployed in Australia. Through a sectoral approach, case study economies can leverage their comparative advantages and niche strengths in specific areas where they have demonstrated relative success in terms of expertise and economic value. In pursuing this route, they can easily extract lessons and feedback which can be applied to other sectors. She also added that Aligned with this approach, regulation must be designed by sector, according to the most impactful practices - because some sectors can be more high polluters. On this note, sponsoring consultation practices using a sectoral approach could be a strong tool, e.g. emission on satellite no one does it better than mining. Finally, she mentioned that our ability to cooperate and improve on these key issues will directly impact our individual and regional benefit. The quest to foster AI technologies to mitigate climate change is very much tied to the existing and impending socio-economic challenges that each economy faces or foresees in the medium-to-long term. For these methods mentioned above to be successful, you need engagement starting from the regulators and among other stakeholders. She also added that her organization proposed the Tiered AI framework for International Collaboration (TAFIC) as a tool to build collaboration. The function of this proposed framework begins between humans, between cities, between economies, regionally and globally. Inherit in moving through these steps is the facilitation of Infrastructure and Policy as either an enabler or a blocker for success. We should consider policy as a key enabler to those institutions, corporations and organisations leading the path

by sector and economy. Given the urgency we have in climate change, policy should work as enabler, increasing trust and enabling the adoption of the technology.
Prof. Supratid also made his point adding the importance of training next generation. From his perspective, the use of AI technologies will be effective when it fosters young scientists so that the knowledge and experience are transferred successfully to them and they can be the important human resources to apply AI technologies in the fight against climate change.
Dr. Srivastava mentioned that The Asia-Pacific region is thus faced with increasingly complex systemic risks, though it can look to AI technologies to help analyse and respond to them. A successful three-track strategy will include smart preparedness, innovative ecosystems and integration of climate risks. First one is ‘Smart preparedness.’ Smart preparedness relies on intelligent solutions to tackle systemic risks and support lifesaving responses. These can take advantage of frontier technologies to improve risk analytics, digital solutions, impact forecasting and early warnings. Second one is ‘Innovation ecosystems.’ Innovation ecosystems incorporate the latest technological and other developments to synchronise institutions, technologies and policies in an agile way and carry out appropriate dynamic scenario planning. Such ecosystems can mitigate trade-offs between competing priorities and ensure that the complete package is cost-effective and risk-informed. Last one is ‘Integrating climate risk and disaster management.’ To prepare for disasters during climate change all infrastructure investment must be risk-informed. Infrastructure in this case covers not only discrete assets such as roads and buildings, but also collective sets of systems that can be synchronized to provide essential services.

Prof. Othman, the chair of the discussion session, finalized the session by highlighting that we need to make sure what the objectives of AI applications are in using AI for any purpose as AI is very customized to problems. Then, she ended the session appreciating all the speakers and participants for their active discussion.

Closing Ceremony

15. Mr. Do-Shick Shin, Executive Director of the APEC Climate Center, concluded the symposium with a speech highlighting the importance of productive presentation and discussion on the application of AI for climate change adaptation. Also, he thanked organizing committee for their hard work and speakers, discussants, and moderators for their contribution. Finally, he thanked all participants for their participations and interests on making APCS 2022 as a successful event. After this, the symposium came to an end.

Annex I. Participants List

#	Economy	Organization	First name	Last name
1	American Samoa	National Weather Service	Hans	Malala
2	Australia	Department of Industry, Science and Resources	Max	Morrison-Smith
3	Bangladesh	Bangabandhu Sheikh Mujibur Rahman Agricultural University	Md Abiar	Rahman
4	Bangladesh	National Oceanographic and Maritime Institute (NOAMI)	Mohan Kumar	Das
5	Brazil	AI Asia Pacific Institute	Kelly	Forbes
6	Brunei Darussalam	Ministry of Development	Alinayati	Perudin
7	Brunei Darussalam	National Disaster Management Centre	Muhammad Nurhazman	Bin Latip
8	Chile	National Agency for Research and Development, Chile	Sharapiya	Kakimova
9	Chile	Pontificial Catholic University of Chile	Rayana	Palharini
10	Chile	Universidad Catolica de Temuco	Angelica	Casanova Katny
11	Chile	Universidad de Antofagasta	Yecid	Jimenez Bellott
12	Chile	Universidad de Atacama	Erica	Castro
13	Egypt	Egyptian Meteorological Authority	Awatif	Mostafa
14	Ethiopia	Ethiopia Meteorology Institute	Abate Getachew	Feleke
15	Ethiopia	Ethiopian Meteorological Institute	Gezahegn	Bekele
16	Hong Kong	University of Exeter	Timothy	Lam
17	India	Indian Institute of Technology Roorkee	Atul	Kumar
18	India	Indian Institute of Tropical Meteorology	Ramesh	Kripalani
19	India	King Mongkut's University of Technology Thonburi	Nishit	Aman
20	India	National Centre of Meteorology	Koteswararao	Kundeti
21	India	NVIDIA corporation	Karthik	Kashinath
22	India	UNESCAP	Sanjay	Srivastava
23	Indonesia	IPB University	Akhmad	Faqih

#	Economy	Organization	First name	Last name
24	Indonesia	Meteorological, Climatological and Geophysical Agency	Dian Nur	Ratri
25	Indonesia	Meteorological, Climatological and Geophysical Agency	Arif	Marufi
26	Indonesia	Meteorological, Climatological, and Geophysical Agency	Nastiti	Andini
27	Indonesia	Meteorological, Climatological, and Geophysical Agency	Mugni Hadi	Hariadi
28	Indonesia	Ministry for Maritime Affairs and Investment	Rita	Octafiani
29	Indonesia	National Research and Innovation Agency	Foni	Agus Setiawan
30	Indonesia	National Research and Innovation Agency	Arnida L	Lafitah
31	Indonesia	National Research and Innovation Agency	Inna	Syafarina
32	Indonesia	National Research and Innovation Agency	Hilman	Pardede
33	Indonesia	National Research and Innovation Agency	Yiyi	Sulaeman
34	Indonesia	National Research and Innovation Agency	Nena Melia	Westi
35	Indonesia	Rimbo Pangan Lestari	Ai	Farida
36	Japan	Japan Meteorological Agency	Noboru	Nemoto
37	Kiribati	Kiribati Meteorological Service	Mwata	Keariki
38	Republic of Korea	APEC Climate Center	Uran	Chung
39	Republic of Korea	APEC Climate Center	Suhee	Han
40	Republic of Korea	APEC Climate Center	Inja	Jeon
41	Republic of Korea	APEC Climate Center	Daeun	Jeong
42	Republic of Korea	APEC Climate Center	Hyung-Jin	Kim
43	Republic of Korea	APEC Climate Center	Seongkyu	Lee
44	Republic of Korea	APEC Climate Center	A-Young	Lim
45	Republic of Korea	APEC Climate Center	Sangwon	Moon
46	Republic of Korea	APEC Climate Center	Kyungwon	Park
47	Republic of Korea	APEC Climate Center	Sugyeong	Park

#	Economy	Organization	First name	Last name
48	Republic of Korea	APEC Climate Center	Jinyoung	Rhee
49	Republic of Korea	APEC Climate Center	Jin Ho	Yoo
50	Republic of Korea	Chungbuk National University	Jiheon	Lee
51	Republic of Korea	Green Technology Center	WonMoo	Kim
52	Republic of Korea	Green Technology Center	Ami	Woo
53	Republic of Korea	Jeonbuk National University	Jisook	Park
54	Republic of Korea	Jinkwang	Charles	Lee
55	Republic of Korea	Korea Institute of Science and Technology	Minhee	Chang
56	Republic of Korea	Korea Water Forum	Mijin	An
57	Republic of Korea	Korean Folk Village Museum	Na	HyeongNam
58	Republic of Korea	Kyonggi University	Myoung-Jin	Um
59	Republic of Korea	Kyoto University	Sunmin	Kim
60	Republic of Korea	National Institute of Meteorological Sciences	seungmin	Jang
61	Republic of Korea	National Institute of Meteorological Sciences	Yeji	Shin
62	Republic of Korea	Seoul National University of Science and Technology	Seonyoung	Park
63	Republic of Korea	Si Analytics (SIA)	Doyi	Kim
64	Lao PDR	Ministry of Natural Resources and Environment	Malabou	Baylatry
65	Malaysia	Department of Agriculture	Nurhazarull Nadia	Baset
66	Malaysia	Department of Agriculture	Norimah	Jumat
67	Malaysia	Department of Agriculture	logeswary	Kalyana sundram
68	Malaysia	Department of Agriculture	Sabariah	Kamis
69	Malaysia	Department of Agriculture	Norhayati	Madiha
70	Malaysia	Department of Agriculture	Nur Zaitasha	Mahmudin
71	Malaysia	Department of Agriculture	Noor Hapeedah	MD Ali

#	Economy	Organization	First name	Last name
72	Malaysia	Department of Agriculture	Firdaus	Md Lazim
73	Malaysia	Department of Agriculture	Shuerni	Mohamad Razi
74	Malaysia	Department of Agriculture	Norhaslinda	Mohammed
75	Malaysia	Department of Agriculture	Mohd Sanusi	Mohd Kasim
76	Malaysia	Department of Agriculture	NUR SYUHADA BINTI	Mohd Noor
77	Malaysia	Department of Agriculture	NUR IZATUL IFFAH	Mohd Suffian
78	Malaysia	Department of Agriculture	Muhammad Zaim	Mumammd Rapidi
79	Malaysia	Department of Agriculture	Lailatul Jumaiyah	Saleh Huddin
80	Malaysia	Department of Agriculture	Saifful Bahri	Abdul Mutalib
81	Malaysia	Department of Agriculture	Wan Nur Aimi	Shabuddin
82	Malaysia	Department of Agriculture	Syed Mohd Iezzat	Syed Abu Bakar
83	Malaysia	Malaysian Meteorological Department	Munirah	Ariffin
84	Malaysia	Malaysian Meteorological Department	NoorAzam	Shaari
85	Malaysia	University of Malaya	Faridah	Othman
86	Mongolia	National University of Mongolia	Munkhtsetseg	Erdenebayar
87	Nepal	Gautam Buddha International Airport Aero Synoptic Station	Nirmala	Regmi
88	New Zealand	Tonkin and Taylor	Bapon	Fakhruddin
89	Pakistan	Global Change Impact Studies Centre	Muhammad	Amjad
90	Pakistan	Pakistan Meteorological Department	Gohar	Ali
91	Pakistan	Global Change Impact Studies Centre	Qudsia	Zafar
92	Pakistan	Pakistan Meteorological Department	Jehangir Ashraf	Awan
93	Pakistan	The University of Agriculture Peshawar Pakistan	Haroon	Khan
94	Papua New Guinea	Department of Agriculture	Anna	Kimam
95	Papua New Guinea	Department of Foreign Affairs and Trade	Robin	Suang

#	Economy	Organization	First name	Last name
96	Papua New Guinea	Ministry of Environment Conservation & Climate Change	Debra	Sungi
97	Peru	Alluz Geociencias	Rosario	Cabrera
98	Peru	Geophysical Institute of Peru	Gerardo	Rivera
99	Peru	Instituto Geofísico del Perú	Luis	Suarez
100	Peru	Instituto Geofísico del Perú	Ken	Takahashi
101	Peru	jacame ings	Jaime	Casafranca Medina
102	Peru	National Service of Meteorology and Hydrology of Peru	waldo	lavado
103	Peru	Universidad Nacional de Ingenieria	Juan Walter	Cabrera Cabrera
104	Philippines	CAI	Jerold Bon	Lago
105	Philippines	Climate Resilient Agriculture Office	Perla	Baltazar
106	Philippines	Climate Resilient Agriculture Office	Alicia	Ilaga
107	Philippines	Department of Science and Technology - Advanced Science and Technology Institute	Karen	Agcaoili
108	Philippines	Department of Science and Technology - Advanced Science and Technology Institute	Jeffrey	Aborot
109	Philippines	Department of Science and Technology - Advanced Science and Technology Institute	Franz	De Leon
110	Philippines	Department of Science and Technology - Advanced Science and Technology Institute	Elmer	Peramo
111	Philippines	Department of Science and Technology - Advanced Science and Technology Institute	Eduardo Jr	Piedad
112	Philippines	Department of Science and Technology - Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD)	Bianca Marie	Domingo
113	Philippines	Philippine Council for Industry, Energy, and Emerging Technology Research and Development (PCIEERD)	Samuel John	Cahimat
114	Philippines	Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA)	Loren Joy	Estrebillo

#	Economy	Organization	First name	Last name
115	Philippines	Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA)	Remedios	Liwanag
116	Philippines	Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA)	Junie	Ruiz
117	Philippines	Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA)	Rusy	Abastillas
118	Philippines	Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA)	Ana Liza	Solis
119	Philippines	Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA)	Kristel Anne Valerie	Villasica
120	Philippines	Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)	Vivian Gay	Aggasid
121	Philippines	Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)	Joey	Figuracion
122	Philippines	UNDP	Sanny	Jegillos
123	Spain	Barcelona Supercomputing Center	Francisco	Doblas-Reyes
124	Switzerland	World Meteorological Organization	Mary	Power
125	Chinese Taipei	Central Weather Bureau	Ming-Ying	Lee
126	Chinese Taipei	Agricultural Technology Research Institute	Su-San	Chang
127	Chinese Taipei	Agricultural Technology Research Institute	Lily Ting-Hsuan	Chu
128	Chinese Taipei	Central Weather Bureau	CHING-TENG	Lee
129	Chinese Taipei	Central Weather Bureau	Ting-Huai	Chang
130	Chinese Taipei	Central Weather Bureau	Hui-Ling	Chang
131	Chinese Taipei	Central Weather Bureau	Jian-Pu	Chen
132	Chinese Taipei	Central Weather Bureau	Meng-Shih	Chen
133	Chinese Taipei	Central Weather Bureau	Shih Chun	Chou
134	Chinese Taipei	Central Weather Bureau	Hsin Yu	Chu
135	Chinese Taipei	Central Weather Bureau	JING-SHAN	Hong

#	Economy	Organization	First name	Last name
136	Chinese Taipei	Central Weather Bureau	Weipeng	Huang
137	Chinese Taipei	Central Weather Bureau	Tzu-Ting	Lo
138	Chinese Taipei	Central Weather Bureau	Yun-Lan	Chen
139	Chinese Taipei	Chung-Hua Institution for Economic Research	Hen-I	Lin
140	Thailand	Bureau of Groundwater Exploration and Potential Assessment	Praphawadee	Otarawanna
141	Thailand	Chulalongkorn University	Aksara	Putthividhya
142	Thailand	Chulalongkorn University	Tanawat	Tangjarusritarat orn
143	Thailand	Climate Center TMD	Hathaichanok	Wongpongsako rn
144	Thailand	Department of Agricultural Extension	Sumana	Simasalit
145	Thailand	Department of Agricultural Extension	Samart	Srewilay
146	Thailand	Department of Agricultural Extension	Margaret	C Yoovatana
147	Thailand	Department of Agricultural Extension	Traprueksa	Tanyakaset
148	Thailand	Department of Disaster Prevention and Mitigation (DDPM)	Somneuk	Swatteuk
149	Thailand	Department of Disaster Prevention and Mitigation (DDPM)	Bhumrindra	Tauvarotama
150	Thailand	Department of Disease Control	Jiraporn_P	Prommongkhol
151	Thailand	Department of Environmental Quality Promotion (DEQP)	Panya	Warapetcharay ut
152	Thailand	Department of marine and coastal resources	Kittirath	Intarasiri
153	Thailand	Department of Marine of Coastal Resources	Chalermrat	Sangmanee
154	Thailand	Department of Public Works and Town & Country Planning	Sariya	Srichuae
155	Thailand	Department of Quality Promotion	chongrak	Thinakul
156	Thailand	Department of Water Resource	Poonnapob	Mankongdee
157	Thailand	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	Chutima	Jongpakdee
158	Thailand	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	Harit	Cheautong
159	Thailand	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	Siwaporn	Tangwanichaga pong

#	Economy	Organization	First name	Last name
160	Thailand	Digital Economy Promotion Agency	Jakkanit	Kananurak
161	Thailand	Forest Research and Development Office	Apiwat	Uaareeleat
162	Thailand	Geo-informatics and space technology development agency (public organization)	Mr.Kulapach	Lhapawong
163	Thailand	Geo-informatics and space technology development agency (public organization)	Pramet	Kaewmesri
164	Thailand	Horticulture research institute	Satja	Prasongsap
165	Thailand	Hydro-Informatics Instititute	Kritanai	Torsri
166	Thailand	Hydro-Informatics Institute	Jirawan	Kamma
167	Thailand	Hydro-Informatics Institute (HII)	Aisawan	Chankarn
168	Thailand	Kasetsart University	Benya	Choemta
169	Thailand	Kasetsart University	Parichart	Promchote
170	Thailand	Marine and Coastal resources research center, the central gulf of Thailand	Praderm	Uttayarnmanee
171	Thailand	Marine department	Somphong	Somnuk
172	Thailand	Meteorological Department	Jessada	Koo-ngammak
173	Thailand	Meteorological Department	Rakchai	Srinuan
174	Thailand	Ministry of Agriculture and Cooperatives	Fuanglada	Tanachote
175	Thailand	Ministry of Digital Economy and Society	Yutthaphong	Sawaengwong
176	Thailand	Ministry of Digital Economy and Society	Chomparee	Chompurat
177	Thailand	Ministry of Interior	Rattikarn	Khambud
178	Thailand	Ministry of Natural Resources and Environment	fairda	malem
179	Thailand	Ministry of Natural Resources and Environment	Pittaya	Laongpan
180	Thailand	Ministry of Public Health	Phattarin	Phongwutthipong
181	Thailand	Ministry of Transport	Sarat	Nitiwongvorakul
182	Thailand	National Energy Technology Center, National Science and Technology Development Agency (NSTDA)	Pidpong	Janta

#	Economy	Organization	First name	Last name
183	Thailand	Office of Forestry Foreign Affairs	Ms.Prattana	Meesincharoen
184	Thailand	Office Of Natural Resources and Environmental Policy and Planning	Netnapa	Saelim
185	Thailand	Office Of Natural Resources and Environmental Policy and Planning	Chompunut	Songkhao
186	Thailand	Office Of Natural Resources and Environmental Policy and Planning	Wasana	Thepsanga
187	Thailand	Office of the National Water Resources(ONWR)	Nilobol	Aranyabhaga
188	Thailand	Office of the National Water Resources(ONWR)	Sumalee	Phungkham
189	Thailand	Pollution Control Department	Sakda	Tridech
190	Thailand	Rangsit University	Seree	Supratid
191	Thailand	Rice Department	Ornanong	Koksungnoen
192	Thailand	Royal Irrigation Department	Somchitthipon g	Amnatsan
193	Thailand	Royal Irrigation Department	Adisorn	Champathong
194	Thailand	Thai Meteorological Department	Trachow	Nichanun
195	Thailand	Thai Meteorological Department	Mongkol	Prongsungnoen
196	Thailand	Thai Meteorological Department	Wattana	Kanbua
197	Thailand	Thai Meteorological Department	Theerachai	Auttachaipanit
198	Thailand	Thai meteorological department	Sotharat	Insawang
199	Thailand	Thai Meteorological Department	Wattana	Kanbua
200	Thailand	Thai Meteorological Department	Fatah	Masthawee
201	Thailand	Thai Meteorological Department	Theeraluk	Pianmana
202	Thailand	Thai Meteorological Department	Jomkhwan	Sakkamart
203	Thailand	Thai Meteorological Department	Wassanun	Sangjun
204	Thailand	Thai Meteorological Department	Kamolrat.	Saringkarnphasi t
205	Thailand	Thai Meteorological Department	Nuthakit	Singhaphet
206	Thailand	Thai Meteorological Department	Chaowat	Siwapornchai

#	Economy	Organization	First name	Last name
207	Thailand	Thai Meteorological Department	Tanat	Tanaboon
208	Thailand	Thai Meteorological Department	Aphantree	Yuttaphan
209	Thailand	Thai Meteorological Department	Wisuta	Theeraratbongkot
210	Thailand	Thai Meteorological Department	Kamol	Promasakha Na Sakolnakhon
211	Thailand	Thai Meteorological Department	Ruthaikarn	Buaphean
212	Thailand	Thai Meteorological Department	Apinya	Chaila
213	Thailand	Thai Meteorological Department	Nuttawut	Dandee
214	Thailand	Thai Meteorological Department	Thanasith	Iamananchai
215	Thailand	Thai Meteorological Department	Chalalai	Jamphon
216	Thailand	Thai Meteorological Department	Amorn	Kaewmorakot
217	Thailand	Thai Meteorological Department	Wirote	Lewcharoenthrap
218	Thailand	Thai Meteorological Department	Payao	Muangngam
219	Thailand	Thai Meteorological Department	Sumreng	Munkong
220	Thailand	Thai Meteorological Department	Roongrawee	Onkot
221	Thailand	Thai Meteorological Department	Thanawut	Panchapornudomlap
222	Thailand	Thai Meteorological Department	Patchara	Petvirojchai
223	Thailand	Thai Meteorological Department	Prasarn	Sangwaldach
224	Thailand	Thai Meteorological Department	Sravodth	Somtrup
225	Thailand	Thai Meteorological Department	Somkuan	Tonjan
226	Thailand	Thai Meteorological Department	Sombhop	wongwilai
227	Thailand	Thai Meteorological Department	Rattana	Prakhammintara
228	Thailand	Thai Meteorological Department	Nulek	Sumranchit
229	Thailand	Thai Meteorological Department	Charkrit	Thongbai
230	Thailand	Thai Meteorological Department	Visuta	Thiraratbongkot

#	Economy	Organization	First name	Last name
231	Thailand	Thai Meteorological Department	Mr.Wira	Samalee
232	Thailand	Thai Meteorological Department	Pariwat	Namduang
233	Republic of Uganda	Uganda National Meteorological Authority	Angella	George Moses
234	United States	Citibank Thailand	Richard	Lomas
235	United States	Citibank Thailand	Pavin	Rodloytuk
236	United States	McGill University	David	Rolnick
237	United States	National Center for APEC	Loraine	Ashcraft
238	United States	National Institute of Standards and Technology	Magdalena	Navarro
239	United States	Texas A&M University	Weiqian	Gao
240	United States	University of Washington	Dale	Durran
241	United States	Utah State University	Simon	Wang
242	United States	World Wildlife Fund	Dave	Thau
243	Vietnam	Center for Environmental Monitoring and Modeling, Hanoi University of Science, VNU University of Science	Hung	Ngo
244	Vietnam	Vietnam Institute of Meteorology, Hydrology and Climate Change	Long Thanh	Pham
245	Vietnam	Vietnam Meteorological and Hydrological Administration	Quang	Nguyen
246	Zambia	ZESCO	Miyanda	Syabwengo