PROCEEDINGS OF THE APEC CLIMATE SYMPOSIUM 2019

PATHWAYS TO SUSTAINABLE GROWTH UNDER A CHANGING CLIMATE:

ENHANCING INTERACTION BETWEEN CLIMATE SCIENCE AND SOCIETY

PUNTA ARENAS, CHILE

AUGUST 20-22, 2019

This document summarizes the presentations and discussions from the APEC Climate Symposium (APCS) 2019, held in Punta Arenas, Chile at the Teaching and Research Assistance Center (CADI), University of Magallanes on August 20-22, 2019

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APCC would like to extend its sincerest thanks to its invited speakers, honoured guests, and all participants for their contributions to the event's success.

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Overview

1. The APEC Climate Symposium 2019 was conducted from August 20-22, 2019 at the Teaching and Research Assistance Center (CADI) in the University of Magallanes in Punta Arenas, Chile. The meeting of the APCC Working Group was also held in conjunction with the event.

2. The event was attended by about 130 participants from 17 economies – Australia, Chile, China, India, Indonesia, Japan, Republic of Korea, Malaysia, New Zealand, Papua New Guinea, Peru, the Philippines, Chinese Taipei, Thailand, The United States, and Viet Nam. The participants included keynote and invited speakers, 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, agriculture, water resources, energy, economics, international development, and decision-making were invited to discuss better connecting provider and user groups of climate information and enhancing the usability and applicability of climate information and services. A complete list of participants can be found in Annex I.

Executive Summary

3. The APEC Climate Symposium 2019, which focused on "Pathway to Sustainable Growth under a Changing Climate: Enhancing Interaction between Climate Science and Society," aimed to support regional technical cooperation, strengthen climate resilience, and produce impactful climate-related policy recommendations. In the opening and keynote, speakers highlighted the importance of sustainable growth in facing of climate change and bridging the gap between climate and application and between scientists and policy-makers to manage climate change. Special focus on Climate Services for Sustainable Development under a Rapidly Changing Climate was dealt in keynote session which provided the impact of climate change in Chile, overview of climate risk management and its relation to climatology, and climate services for health sector. The first session, Understanding of Extreme Climate Events and their impacts, focused on the trends and impacts of extreme weather and climate events and how to minimize its negative impacts to the society. The second session, Innovating Early Warning System to Manage Impacts of Climate Extremes, discussed the key elements for developing early warning system and risk management to reduce adverse impact of climate extremes and how to manage multi-hazards in order to enhance the usability of information. Finally, in the third session of Connecting Climate Information to Socio-Economic Values, topics related to various climate services from regional and global agencies and from different perspectives and how to promote the socio-economic values of climate information. To close the event, a final panel session was held. Experts brought together their varied experience and knowledge to build a more cohesive idea of how to enhance socio-economic usability of climate information services to create sustainable

adaption to climate change, how to reduce perception gaps in disaster risk management sectors in climate information, and the roles of scientists to promote communication amongst relevant sectors.

Opening Ceremony

4. The APEC Climate Symposium 2019 opened on Tuesday, August 20, 2019. The Opening Ceremony began at 9:00 am 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-hosts and partners from the National Weather Service of Chile (DMC), University of Magallanes, and APEC Chile Office 2019 for their help putting together the event. Ms. Moon then introduced Dr. Won-Tae Kwon, the Executive Director of APCC, for her Opening Remarks. Dr. Kwon started her Opening Remarks by sending her appreciation to the co-hosts and participants and spoke about the significance of this event in achieving sustainable growth in the face of climate change especially in Chile. Deputy Director of National Weather Service of Chile provided his Welcome Remarks. He spoke about the importance of actions for adapting climate change in Punta Arenas and Chile and the importance of climate information. This was followed by another Welcome Remarks by Juan Oyarzo Perez, President of University of Magallanes, who stressed the efforts of scientific and political actions in adapting climate change and its impacts. He also welcomed all participants to the meeting to have a fruitful discussion. Then, the Regional Governor of Magallanes, Jose Fernandez Dubrock, gave a Congratulatory Remarks with the emphasis of the impact of climate change in Antarctic and Magallanes. The opening ceremony was followed by the presentation of commemorative plaques of appreciation from APCC to the Region of Magallanes, City of Punta Arenas, National Weather Service of Chile, University of Magallanes, and APEC Chile Office. The session was closed with a group photo.

Keynote Session: Climate Services for Sustainable Development under a Rapidly Changing Climate

5. The Keynote Session commenced at 10:00 a.m. and consisted of the speeches by three distinguished experts on climate change and climate risk management in climate-sensitive sectors. The main theme was how climate services could contribute to achieving sustainable development as well as how sciences could be translated into decision-making to impact the public. The session was chaired by Dr. Jin Ho Yoo, the Director of Climate Services and Research Division, APEC Climate Center.

6. **Dr. Marcelo Leppe, Director of Chilean Antarctic Institute, "Reflecting about Antarctic: Their Role in a Changing Planet"**

Chilean ecosystem ranges from world's driest desert to ice fields in south Patagonia. Dr. Marcelo Leppe expressed that it is a 'climate laboratory'. In March 2015, the heaviest rainfall in 80 years in the Atacama caused heavy flooding, $300 million USD, deaths and damage. This was caused by cold front hitting the Andes, producing rain instead of snow. Current unprecedented drought has been ongoing for past 10 years, created heatwaves and increased frequency of forest fires. 2017 wildfires burnt 273,000 hectares (1 thousands square miles) and killed at least 10 people. This is the worst fire outbreak in the nation's history, affecting Chilean biodiversity (in particular a global hotspot for biodiversity), which has now lost 70% of its original inhabitants. Rainfall is increasing in the South, and extreme rain has triggered flash floods and landslides. Outside of Greenland, southern Chile has the largest area of non-polar ice. Dr. Leppe showed examples of extreme thinning of ice/glaciers, and the 'Grey Glacier'.

Then, he showed a plot of Humboldt's line of eternal snow (elevation versus latitude). Humboldt visited Chile and Ecuador in 1802. These lines are of course changing see https://www.pnas.org/content/112/41/12741. He explained some thoughts on global climate change by Scotese (2016). Most sensitive areas are in high latitudes - as the world warms, lines of eternal snow moves higher as polar temperature gradients reduce. He also explained the impacts to Andes/Chilean ice fields, moving from 'ice house' to 'hot house' and there are changes in ocean circulation - Antarctic Ocean currents (born 30 million years ago when South America left Antarctica). Humboldt Current is one of the most important cold water currents in the world. It impacts Chile and Peru by producing dry deserts and bountiful fisheries in South America and affecting transport of nutrients and moisture. Southern ocean is the only global encircling ocean, and it impacts Antarctic sea ice dynamics. Glacial retreat is global, and glacial ice has been biggest role in global sea level rise. Chilean glacial retreat is strong, and Chile has the Southern Hemisphere's largest glaciers. In 6 year period, Patagonian ice fields have lost ice at a rate of over 21 GigaTonnes/year, which is equivalent to adding 0.06mm to sea level. Dr. Leppe pointed out that only one glacier in Patagonia is stable and the rest are losing mass. 15% of global glacier loss

contributes to 2% of global sea level rise, and Antarctic ice has a bigger role in Climate Change.

Since 2014, Antarctic sea ice has suffered great fall losing as much in the last 4 years as the Arctic has in the last 34 years. The loss of sea ice increases heat uptake of polar oceans Antarctic sea ice had been gradually increasing during 40 years of measurement and reached a record maximum in 2014, before falling markedly. Antarctica has 8 times more sea ice than Greenland and 50 times more surface ice than all mountain glaciers combined. The worst case scenarios would be West Antarctic ice sheet collapses and increases global sea level by 5 meters. 87% of Antarctic glaciers have retreated in last 50 years.

The Pliocene epoch was the last time Antarctica had same CO2 levels, mean global temperature was 16.5 degrees Celsius (compared with 14.5 today) and sea level was 15 meters higher. In Pliocene, East Antarctica had warm summers, similar to Cape Horn biosphere, and West Antarctic ice sheet may have collapsed. Biodiversity and ecosystem response to Climate Change are major research area as well as monitoring disappearance of species with high sensitivity to salinity.

Ocean acidification also affects species with calcium skeletons. The Southern Ocean is acidifying more rapidly than equatorial regions (as is the Arctic and North Atlantic and North Pacific). Bleaching of Great Barrier Reef in Australia is a great example. Ocean acidity is the highest it's been in the past 350 million years. Humans are creating impacts across geological time scales. Thermal sensitivity of tropical fish is high and Great Barrier Reef has bleached severely, 42-54% bleached in past two years. 'Black carbon' soot particles are caused by incomplete combustion. These sediments affect albedo and increase surface warming of ice and also affect cloud nucleation and rain cycles.

Dr. Leppe then introduced 'alien' species in Antarctica. It has been shown that alien species and pathogens can be resilient and the alien species to Antarctic such as crab, grasses, insects, viruses, and bacteria compete for ecosystem space in a warming world with existing species.

The recently adopted Ross Sea Marine Protected Area (MPA), the second international MPA adopted in Antarctica, is an example of progress in implementing conservation measures. However, the efficacy of these MPAs in meeting protection objectives remains unknown – particularly given some of the trade-offs required for approval. In this context, Chile and Argentina propose new protected park in Antarctica with three areas including special protection of fishery, scientific research on krill, and general protection but no consensus reached amongst other Antarctic members.

Then, Dr. Leppe mentioned the Chilean heatwave of February 2019. The city of Valdivia reached 38.5 ℃ in February 2019, and Osorno reached 36.5 ℃ breaking 1953 record. Puerto Natales hit 29.2 ℃ during the February 2019 heatwave. There were three Chilean records in 2019 so far.

According to CAT (Climate Action Tracker) country rating, Chile is highly insufficient to meet COP21 meetings. Chilean policies are consistent with 4 degree warming.

But Chile is also showing clear progress, as Dr. Leppe stated and pointing out that COP25 is in Chile. He also stated that climate change is not faith or religion and massive group of evidence pointing in the same direction.

Antarctic Peninsula near Chile is a 'climate thermometer' and Chile is placed in a position of inescapable vulnerability. He highlighted that the fragility can only be overcome with cooperative work. And science is common language that connects nations.

7. **Prof. Glenn McGregor, Professor of Climatology, Durham University, "Climatology in Support of Climate Risk Management"**

Professor Glenn McGregor started his talky by stating climatology as a discipline which studies and analyses the climate system, investigating boundary conditions that create weather. It looks at cryosphere, biosphere, hydrosphere, land surface, etc. The causes of climate events occur across multiple time and spatial scales and it is concerned with impacts of climate events. The goal is to produce 'actionable' or 'usable' science related to climate risks.

Prof. McGregor then introduced the IPCC framing risk as intersection and interaction between hazards, vulnerability, and exposure. Climate science often looks at hazards but increasingly looks at vulnerability. He introduced the Climate Risk Management definition from Travis and Bates 2014 as a multi-disciplinary activity. In climate risk planning cycle, climatology has a role in all the generic steps of identifying problems, assessing vulnerabilities, determining risks, identifying how to reduce the risks, and prioritizing risk reduction measures. And the steps are an iterative process that if the information is not useful, then more information needs to be gathered.

Successful elements of Climate Risk Management are proposed. The elements involve, firstly, demand driven and problem focused approach. Often users and stakeholders do not realize they have a problem. Scientists often have to work with users. Also, it requires effective policy frameworks. And, high quality data and information are required, which are produced by climate science community. And appropriate climate services with capacity and capability are needed as well as effective communication between stakeholder groups, engaging deeply. Also, user friendly decisions support tools and methods that show how climate variables will affect specific outcomes such as health, crop outcomes are needed. And it needs sufficient resources for decision makers to use information effectively. Stakeholder participation is essential. Whole community must be involved in managing climate risk. Functioning media is necessary to communicate risk and capacity building occurs at different levels, such as outreach services.

There are some lessons from Climate Risk Management projects. Firstly, it is most effective when climate information services are integrated into decision making frameworks. Climate information must be credible and observation networks must be robust. Unfortunately, many nations are reducing Climate observation networks at this time. Media and extension services are vital. Economic analysis of the value of

climate services is lacking. This harms our business case and it must produce convincing evidence that climate services have economic impact.

Then, Prof. McGregor stated the role of climate information for Climate Risk Management. It uses historical data to contextualize trends and analyze modes of variability. Long range forecasts and predictions are one arm of climate information services. Climate information time scales are relevant for different decision making processes and actions. Credibility is a big issue for weather/climate community. And seasonal to internannual predictability (ENSO) has big room for improvement.

He stated that it is all agreed that climate information is great. However, it needs to be conscious of value chain of linking climate knowledge to action. All scales should be linked across the range of potential players including private sectors.

In terms of micro to macro level of climate information use, the macro level of drivers could be a government convinced that climate information is essential for future planning while the micro level could be end-users who understand the impacts of extremes. The barriers to climate information use are that government may ignore climate change and not support climate information services and companies and end users may not use climate information services. He then commented on how to bridge the gap between knowledge and action. A seamless flow from producers to users, but constraints may restrict user space. He argued to avoid 'loading dock' approach which is just shoving products out the door and there is no customer support or interaction, or communication between the producer and end user. And He suggested a co-production approach and stressed the importance of collaborative and flexible approach.

Prof. McGregor introduced, as climate information for risk management, ENSO and South Pacific health outcomes: the case of Diarrhea. Diarrhea is still accounted for millions of global deaths. The 2015-16 El Nino event created extreme drought and water shortages in South West Pacific, which impacted food availability and water quality. World Health Organization (WHO) predicted diarrhea would increase, and this formed the motivation for this study. The study started by understanding pathways between climate/weather variation and rate of diarrheal disease. The source data of climate was from ERA interim for atmospheric data, NOAA for ocean data, and health data from Pacific Syndromic Surveillance System which records weekly health data, but data coverage was limited (often only one point per an economy). The focusing area was Solomon Islands and 2015-16 El Nino was in context. Health data was available from 2010 onwards, where the Pacific shifted from La Nina to El Nino. Solomon Islands experienced severe rainfall deficiencies, severe drought, and fresh water supply issues. In terms of rainfall, ENSO and diarrhea relationship, there was significant increase in diarrhea during El Nino as opposed to La Nina. There was a strong association with 3-month lagged rainfall and current diarrhea rates. Then, he raised a question that if there is a relationship, could a seasonal forecast of rainfall be useful for health services? Or does it help fresh water infrastructure planning for dry seasons? These questions led to developing ENSO – Health alert services, he stated. Firstly vulnerability measures, health observations, and climate observations were collected to produce ENSO – health associations. Then, the global WMO S2S forecast

databases were used to create the system. ENSO events create shock to health model, and create an ENSO health plan to manage impacts on Pacific Island countries. Prof. McGregor also added that integrated climate and health observing systems and analysis would create better management of health risks.

8. **Dr. Joy Shumake-Guillemot, Officer in Charge of WMO-WHO Joint Office, "Climate Services for Health – Realizing Social Impacts"**

Dr. Joy Shumake-Guillemot introduced herself as an officer in charge of Joint Office of climate and health representing WMO and WHO. She raised a series of issues: how is climate information used by health community?; how to unlock potential for climate action to protect health sector from climate change?; and how health and climate interact within Sustainable Development Goals (SDGs)? She then examined health in the SDG era, in the beginning, middle and end of SDG process. She stated that it would be impossible to create peaceful and sustainable societies without healthy societies. And the scorecard of success is related to health outcomes: clean water, safe cities, education, etc. Health of biosphere, land cycles, and climate determinates to achieving sustainable societies and effective economies. She also pointed out losses and damages (including entire Pacific Island states) will be incurred if low carbon transition is not achieved. And climate information is to help guide to a safer world.

She explained that climate and health are coupled. For example, the United States is experiencing health impacts via temperature extremes, fires, and vector-borne diseases. These are common to Pacific Islands. Climate change exacerbates exposures and vulnerabilities. She also pointed out diseases, flooding preparation, and mental health issues require different types of inputs and policies. Health system requires systemic and holistic approach. In order to adapt to climate change shocks and stresses, strong partnerships with climate community are needed.

WMO for past 3 years had tracked National Meteorological and Hydrological Services (NMHS) working with health sector. Only 70 member economies are working with health sectors in climate change adaptation and mitigation. This is a critical issue to give better support to health sector.

Dr. Shumake-Guillemot suggested four opportunities with climate science community. Public health community has two centuries of success in shaping society and understanding what brings harm to people and bringing evidence-based methods to change behavior and perceptions (road safety, smoking, vaccination, and safe sex). Health communities are essential partners and actors in shaping climate action and convincing politicians and citizens. It also mobilizes when convinced of a threat and is now convinced that climate change is an emergency and are ready to act. There are three key things to understand when advocating: 1) doctors are trusted voices, 2) people care about their health and their kids, and 3) health messages of the benefits of climate change mitigation resonate. Shifting to low carbon economy has health impacts too (air quality etc.).

She then introduced the large global movement in health community to support. Firstly, “Empower: educate and inform people”. This is to change minds not the climate. She argued that we should all be concerned citizens using science for climate action and help empower actors with our knowledge via training, impact assessments, translation, and communication to public. Then, she introduced an example of WHO/UNFCCC climate and health country profiles and policy tools which help health ministries. This is to help to advocate for themselves and government. A second example is tailoring local information in the US with extreme heat. Downscaled projections are provided for which US cities are impacted by extreme heat, taking down to decisions scale (county level) and congressional district.

Secondly, “Discover potential”. It is a myth that health people do not know what climate information they want. The real issue is that health community does not understand the potential of climate information services and forecasts and opportunities of climate science to deliver better decision tools. Health community needs as much high-resolution historical data as possible to find out how climate drives health outcomes. This information would be used for future predictions for planning and programming.

She then explained the importance of understanding expectations of climate information. Health Community has high standards as they make life/death decisions, and therefore, credible, reliable, high ethical and professional standards are needed to avoid malpractice or harm. She then introduced EIOS (Epidemic Intelligence from Open Sources initiative) as an example of global detection by WHO. The short video was shared to show how to minimize impacts and avert future crisis. EIOS scans reports and data globally. This initiative is one of the forefront projects of using big data and AI to detect new diseases. She also introduced few projects of integrated data management systems such as European Environment and Epidemioloogy (E3) Network, Brazil Climate and Health Observatory, IRI Maprooms Climate Library, and Healthy Futures given that health community wants integrated information systems to allow real-time monitoring. Also, there is mobile health (M-Health) using mobile data. Currently, 6 billion people have mobile subscriptions. This changes the way of providing health care, and how to communicate and interact with communities. Using existing data collection and service management, the community can create mobile risk advisory applications (e.g. DHIS 2), and in the future it would be possible to provide warnings of pollen or heat risk, or how close you are to a cooling center, virtual medicine, or biosensors. The community can push meteorological warnings (see ongoing project in Malawi) and health information too.

Dr. Shumake-Guillemot introduced the third movement of “Co-design services to meet needs.” She explained the 2nd myth of 'producers and users'. She pointed out that early warning systems are not 'off the shelf' but it is about people. Users have no ownership for off-the-shelf products. Therefore, she argued to use the term of ‘partners’ instead of ‘users’. She explained that climate services are mission-orientated partnerships driven by social needs which result in the production and delivery of fit-for-purpose relevant, authoritative, timely and usable information about climate change, climate variability, trends, and impacts to improve decision-making

in climate sensitive sectors. Also, she stated that it is important to identify readiness of health community and other sectors for uptake of climate information in co-design. And identifying what is being done and working is also important. She introduced a book of Climate Services for Health, a guidance document with 40 examples of how climate information is used across time scales and identifies past issues, identifies bottlenecks and how to unplug them.

Lastly, she introduced "Integrate: All sectors are health sectors." Water, energy, cities, and food are some of the related sectors. She argued that new frontier of climate services is "integrating" risk across time scales, continual evaluation from science to service process with iterative feedback, multi-hazard (meteorology, hydrology, water, and land), multi-sectorial (agricultural, health, etc.), and multi-disciplinary and cross-trained people. She provided an example of integrating multi-disciplinary as Caribbean Integrated Health Services. She also pointed out that integration is the most cost-efficient way by providing best impacts.

She also explained that WMO understands that more NHMSs need to include more health interactions and recent WMO congress recognized the need to include health sector.

She concluded her talk by stating that empower your partners in health community, discover the possibilities, and co-design integrated projects and products.

9. **Wrap-up and Discussion:**

The discussion began with a question from the audience to Prof. Glenn McGregor and Dr. Joy Shumake-Guillemot. A representative from Indonesian Meteorology, Climatology, and Geophysical Agency (BMKG) explained BMKG has developed climate early warning system for health sector for Dengue outbreak. Their experience indicates the characterization of local climate, for example, in one city it was found temperature is strongest factor while it is humidity in another city. Incident rates vary greatly from city to city and they need to have massive research and study on this. He asked how they can leverage big data and AI. Prof. McGregor answered that Dengue is very interesting and geographical and spatial variations are driven by local exposure. He suggested social factors come into play which interacts with local climate. Exposure is driven by water and containers, which are potential breeding sites for mosquitos. It is not just about climate, but it is also climate drivers which interact with social and economic landscape. He also stated that vulnerability will change and Timescales are important. Dr. Joy Shumake-Guillemot mentioned that at the municipal level, it would be beneficial to aggregate at national scale to see stronger trends of social and climate drivers.

There was a question from a representative from Papua New Guinea National Weather Service. In small economies, getting data is a big challenge. While Meteorological service provides reliable data, other sectors (for example, health community and agriculture) lack information. Sector specific products are challenging. Examples from Solomon Islands and other WMO projects are very useful for small islands. Lack of data limits the national capabilities. He asked if there is any guidance

on how the data can be made in those sectors. Also, PNG faces Malaria in highlands. There is no data, but there is a big influx of people moving from highlands to coast. He asked how to quantify effect of migration to/from coast. Dr. Joy Shumake-Guillemot answered that, in terms of Malaria control program, she suggest asking health community and people of their worries. What social science have they done about population migration? Is it a priority? What kind of information do they have? For local interactions and transmission patterns, local information would be needed. Also, she suggested finding what kids of data or studies have already been done. WHO are building a global data portal for health science, allowing sharing national data and information (where relevant) to unlock some data issues. Also she mentioned that he may find he does not need local data, but he may have strong signals from the environment from remote sensing information. Prof. Glenn McGregor also answered the question regarding Malaria that it follows the road networks back into the highlands, and people become infected near the coast and bring it back to the mountains. He then pointed the importance of communicating with climate or health community and starting a partnership with them. Often it comes to a surprise that data does exist but do not find the right person.

A representative from Malaysian Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC) mentioned the role of Antarctica in regulating global climate and that they are proud to participate and contribute to Antarctic programs. She also stated that they would like to contribute more and thank the Chile government for their assistance. Dr. Marcelo Leppe stated that they have received Malaysian scientists several times and their stations are open to international collaboration. He stated that it is the original signatories to Antarctic agreement.

There was a question from the audience regarding interdisciplinary and social studies, and if there is possibilities to move into interdisciplinary approach with Antarctic research or in Punta Arenas. Dr. Marcelo Leppe mentioned that he came from science and his institute (INACH) during last 12 years has understood the importance of science communication and perception of people (in Chile and in Punta Arenas). He also stated that most people do not understand how Antarctic influences their everyday lifestyles. In Chile, 90% of the coast interacts with Humboldt Current and they understand how Humboldt changes the Chilean landscape. High temperature in North Antarctic peninsula influences Atacama extreme rainfalls in days later (daily teleconnections). And he and his team are trying to convince authorities that they need useful information to make better decisions. In terms of connecting Chile via fiber-optics, he also mentioned that there are efforts to convince authorities to bring a 16 TB/s line into Antarctica, the longest fiber communications line with Punta Arenas. He also stated that it has been noticed that there were anomalous disease outbreaks in northern Chile. As from a region and economy based on migration, Chilean people need to understand how these are related to landscape and how these will react to changing conditions. And it is a big challenge to go to politicians and schools.

There was a question from Prof. Jin-Yi Yu from University of California – Irvine, that if there are indications that climate impacts are more powerful on human health and how 2016-17 El Nino impacts compared with 97-98 El Nino. Prof. McGregor stated

that for the first question it is difficult since historical health data is not available. But he said that rainfall anomalies did exist and theoretically it would more impact on human health. He also said that data properly exists, and it needs to be discovered in the health records. Detection and attribution of current events are ongoing. In order to attribute health events to climate impacts, it needs more health data. Dr. Shumake-Guillemot stated that, in East Africa, there were strong signals and big outbreaks of diarrheal diseases in 97-98. In 2015-16, Cholera outbreaks were predicted. Local Meteorological agencies were hesitant to act on global forecasts, and they wanted to wait for regional consensus before approaching local government. However the consensus did not arrive until cholera outbreaks began in Dar-es Salaam. This hesitancy to act is an important lesson when making social impacts; to have flexibility and faith to bypass bureaucracy. The outbreak lasted for over 18 months with more than 70,000 cases and took years to control. She pointed out the great potential opportunities to avoid these outbreaks based on lessons learned.

Prof. McGregor also mentioned that Marshall Islands had a clear spike in 97-98. But there was no signal in 2015-16. This was because that Marshall Islands learnt from previous experiences and created intervention strategies. Provisions (e.g. bottled water) helped avoid damages and he highlighted that the history could teach us important lessons.

There was a question from Dr. Jin Ho Yoo from APCC to Dr. Marcello Leppe that while climate change is becoming more severe as shown from his talk, the perception and people’s interest are not as high as expected and how to solve this issue. Dr. Leppe provided COP25 as a good opportunity to socialize importance of understanding Antarctica for Climate Change. Globally Antarctica is relevant to Chile. 20 years ago people used to ski down the streets in Punta Arenas, but now it has become a 'myth'. Recent Patagonian/Andes ice cores show change is occurring rapidly. Chile is the single economy in the southern hemisphere that experiences such temperature gradients and this would be the message in COP25. He also mentioned that they seek to change Antarctic treaty system as he is also in the Department of Foreign Affairs. Connecting the science and policy worlds will be difficult.

Another question from Dr. Jin Ho Yoo to Prof. McGregor and Dr. Shumake-Guillemot was followed. He stated that this opportunity is to facilitate or increase the uptake of climate information services and that the power of health community in advocacy is impressive. He also stated that people's changes to smoking are a useful analogue to dealing with climate issue and that health issue is directly related to people's own well-being and 'profit'. However, climate action is a little removed from their own interest. He asked how to take this health community advocacy for climate action and expand the user space of climate information services. Dr. Shumake-Guillemot firstly responded that social change is going to happen by building stronger arguments. And the community needs to pay attention to packaging solutions such as making solutions available and accessible to people and how to organize their daily lives. In addition to COP25, there is UN action summit to package actionable solutions. For example, there are opportunities to shift to Electric Vehicles (EVs), charging stations etc. (France provides a subsidy and 80% off road tolls for EVs).

Countries need to make it easy to shift to these options. EVs create cleaner air right now, which affects asthma attacks in children. Prof. McGregor stated that an effective strategy is demonstration projects, e.g. climate information can improve management of climate-related risk. He provided his experience on working on heat, which has direct impact on health. There is a clear pathway between weather and climate and health impact. Benefits of advanced information regarding heatwaves are clear for health sector. Health community has intervention strategies and actions to reduce risk to the vulnerable (e.g. elderly, young). He also talked about public perception that the perceptions are age-related. There is increasing awareness in the younger generations and they will push changes as they will be impacted the most.

Finally, Dr. Jin Ho Yoo closed the keynote session with his gratitude to the audience and the three speakers.

Session I: Understanding of Extreme Climate Events and their Impacts

10. Session I started at 13:30 of August 20, 2019. This session discussed the recent trends, impacts, and the causes of extreme weather and climate events and how to minimize the negative impacts. This session was chaired by Dr. Seontae Kim, Research Fellow of Climate Analytics Department, APEC Climate Center.

11. **Dr. Arun Kumar, Principal Scientist of Climate Prediction Center/NCEP/NWS/NOAA, "Global Infrastructure for Predicting Climate Variability and its Potential for Anticipating Changes in the Occurrence of Local Climate Extreme"**

Dr. Arun Kumar started his presentation by providing the definition of weather and climate extremes. He explained that daily variations occur across timescales, locations, precipitation, temp, soil moisture etc. A long record allows a frequency distribution to be created and changes in this Probability Density Function (PDF) can be assessed over time. Extremes can be defined using these PDFs from a scientific point of view. It is impact independent, purely driven by historical data. He also stated that societal impacts are related to local vulnerabilities, local climatologies, and local season onsets (e.g. wet or dry season). And extremes of various variables need to be related to facets of society which affect human and livestock health and incur economic losses due to heat/cold waves, droughts, and floods. He explained that most variables have a normal distribution except precipitation and PDFs can be constructed for any timescale.

Dr. Kumar also explained that the extremes can be correlated, for example, hot, dry, and windy temperature could impact bushfires, hot and humid condition could create health impacts, or cyclones and tides could create more storm surges. Societal impacts are worse for multiple extremes. And how much impacts the extremes causes depends on local conditions and seasons. He also showed a chart from Insurance Information Institute (III) which indicated the insurance losses from extremes are increasing.

Then, Dr. Kumar explained how to make extended range of predictions of the extremes. Various modes of variability (ENSO – El Nino and Southern Oscillation, NAO – North Atlantic Oscillation, SAM – Southern Annular Mode) plus changes in trends will change the PDF at various locations and timescales. PDFs can shift (creating a new mean), can spread (increasing the variance) or both. When a PDF shifts, one extreme increases and the other decreases. With increased variability, chances of extremes at both tails can increase. Climate modes of variability will affect the PDF of a variable at a given location. Dr. Kumar then explained how this extended range of prediction would change the PDFs at a given location, which could allow people to anticipate the future climate extremes. Links between modes of climate variability and local extremes can be used for the prediction of extremes. Dr. Kumar provided a few examples such as ENSO and extreme rain/mudslides in Peru during El Nino while causing fire danger in Indonesia and NAO linked to cold extremes in the Eastern USA. Building a catalogue of how these modes of variability affect the local climate would benefit the prediction of extremes.

Then, Dr. Kumar introduced the World Meteorological Organization (WMO) infrastructure for long-range forecasts. WMO currently maintains several Global Producing Centers (GPCs) for Long-Range forecasts (seasonal) and the outlooks are issued monthly. Now new GPCs exist for annual to decadal climate predictions. Also, Regional Climate Outlook Forums (RCOFS) are hosted by Regional Climate Centers (RCCs). These 'operational' entities support the WMO Global Framework for Climate Services (GFCS).

For operational infrastructure for seasonal forecast, there are 13 GPCs producing seasonal forecasts every month, which are fed into the Multi-Model Ensemble (MME) hosted by Korean Meteorological Agency (Lead Center for Long Range Forecast Multi-Model Ensemble, LC-LRFMME). LC-LRFMME disseminates the data to NMHSs, RCCs, and other organizations, where the digital data is password protected while charts are publically available.

UK Met Office (UKMO) leads an effort to provide Annual to Decadal Climate Predictions (ADCP). Outlooks updated once a year with year 1 and average of year 2-5 outlooks. It is usually updated around November-December for the following years. These forecasts can be used to infer changes in extremes at the regional level.

There is S2S (seasonal to sub-seasonal) project, a joint WWRP/WCRP research project. It is not operational yet, but realtime forecasts should be available within the year. Dr. Kumar also mentioned that cascade of long-range forecasts from GPCs to RCCs and RCOFs is sent to NMHSs.

Dr. Kumar finalized his presentation by stating that, in order to use the prediction information, people needs to collect the global scale forecasts, assess the change in the mean, and then people can develop outlooks in extremes at local levels based on historical data of how modes of variability affect the interested region.

12. **Prof. Jin-Yi Yu, Professor of University of California, Irvine, "The Changing El Niño in the 21st Century: Properties, Dynamics, and Impact"**

Prof. Jin-Yi Yu explained the changes in 20th century (20C) El Nino and 21st century (21C) El Nino as well as its different impacts. 97-98 El Nino is a 'classic' 20C El Nino, but others such as 77-78 El Nino were 'central Pacific' El Nino – warm water was coming from California and Mexico. In 21C, all El Nino events are 'central' that not much warm current comes from Peru. 2009-2010 El Nino was the strongest one observed so far, again formed at the dateline. 2006-07 was a combination of both.

The 2015-16 El Nino was again a very strong El Nino, similar to 97-98, but the anomalies began at the dateline before warm anomalies began off Peru. California did not get wet anomalies in 2015-16 El Nino. So far, in 21C cases, warm water initiates off California and Mexico. 2018-19 El Nino was again initiated off North America.

He proposed the difference between Eastern Pacific (EP) and Central Pacific (CP) El Nino; these are two different physical phenomena. Additional CP El Nino may not be predicted in same away as EP Pacific. CP El Nino provides with less lead-time, that is looking at warm water off Australia would not provide forecast warning. In EP El Nino, the tropical ocean interacts with tropical atmosphere via the Walker Circulation.

This is very sensitive to ocean temperatures off South American coast. For CP El Nino, it relies more on the Hadley Circulation and warm water near Indonesia/Australia is taken to North America and later South America via the Hadley circulation. CP El Nino is very shallow and is related to Tropical Ocean interacting with the sub-tropical atmosphere. It is influenced by winds from North America, with far less predictability than ocean off South America. Also CP El Nino and EP El Nino have different dynamics; CP El Nino is mixed-layer dynamics while EP El Nino is thermocline dynamics.

The evolution patterns are different. In 20C, tropical ocean/atmosphere coupling was very strong, which often creates La Nina following El Nino with periodic variations. In 21C, El Nino occurs via subtropical pacific coupling, far more variability, less periodic. This has more complex evolution patterns.

Then, Prof. Yu explained the influence of warm water in dateline to global circulation. 20C produces wave train into the US from California, creating cold conditions in California and warm and wet Northeast USA. 21C CP El Nino creates wave train into Alaska/Canada and then into the US from the Northwest direction. This influenced to warm and wet in Northeast USA with cold in Florida. Prof. Yu pointed out that orange growers in California have to adapt to ENSO impacts differently, likewise in Florida.

CP El Nino affects Indian Ocean differently compared with EP El Nino. In 20C the Indian Ocean is 'slave' to Pacific, with 3 month lag of warming. Indian Ocean is independent of Pacific in 21C. There is no teleconection which creates warming in Indian Ocean – no Walker Circulation coupling. Warm Indian Ocean affects West Pacific South Tropical High (WPSH), including typhoon genesis. In 21C, WPSH is now influenced by maritime continent. WPSH changed its behavior in 1993, and now has different periodicity. Climate has gone through transition into a different regime.

Prof. Yu also mentioned that in 20C, El Nino occurred every 4 years, and now it is expected that CP El Nino occurs every two years.

He also introduced the impact of El Nino on Antarctic climate and SAM. Correlation between ENSO and SAM shifted in early 90's. There used to be weak or no correlation, but now it is < -0.4. ENSO now has strong impact on Antarctic climate. Also, latitudinal rainfall summer patterns in China have changed. Now there are two regions (dry and wet) as opposed to 3/4 latitudinal regions of rainfall during summer.

Then, he raised a question why 21C El Nino is so different and if it is due to Global Warming. He commented that there is no going back to 20C, and since Atlantic Ocean is warm, the Atlantic Meridional Oscillation (AMO) changed after 1990. El Nino may go back to 20C patterns if AMO switches back to a cold phase in the future. He finalized his talk by stating that it would be a great opportunity for climate scientists to examine how earth's climate system operates.

13. **Dr. Paul Gregory, Senior Prediction Scientist of Bureau of Meteorology, Australia, "Forecasting of extreme weather events from sub-seasonal to decadal timescales"**

Dr. Paul Gregory began his presentation by reviewing recent climate trends experienced in Australia. One of the most significant trends has been the reduction in rainfall over southern Australia during the cooler months. Two research programs in conjunction with CSIRO (Commonwealth Scientific and Industrial Research Organization) and State Governments have done much to inform governments and infrastructure managers about these future trends. These were the Indian Ocean Climate Initiative begun in 1997 and the South-East Australian Climate Initiative in 2005. Both programs have informed such projects as desalination plants for metropolitan water supplies. Over the same period, rainfall in Northern Australia during the wet season has increased. This has been attributed to the expansion of the Hadley Circulation; similar impacts have been observed in other mid-latitude countries around the globe. He also explained that Australia continues to warm, with roughly linear warming trend and rapidly increasing frequency of extreme heat events. He then explained that increasing temperature extremes and changes in rainfall increases the risk of many hazards such as bushfire, sea level rise which implies tidal flooding or erosion due to storm surge, coastal flooding, etc. In Australia, recent cases show record-breaking heats and fires and January 2019 is now Australia's hottest month on record. The recent summer generated a range of climate impacts, highlighting the challenges facing agencies such as the Bureau of Meteorology (BOM).

Then, Dr. Gregory introduced the BOM's existing suite of long-range forecast products available to the general public. Many of the products are based on the Bureau's own ACCESS-S1 model, a coupled ocean atmosphere model based on the UKMO GloSea5 system. BOM issues monthly and seasonal outlooks with probability of above/below median rainfall, maximum temperature, minimum temperature, and probability of exceedance (POE) for rainfall. He also mentioned that these outlooks would be issued weekly for seasonal and sub-seasonal timescales and would include outlooks of temperature anomalies. And the model outputs are also used for Northern rainfall onset (Monsoon onset) products, and sea surface temperature forecasts. Forecasts of ENSO and IOD (Indian Ocean Dipole) are provided as well, which include ACESS-S1 module plumes for various ENSO and IOD indices and model outputs from many global centers. He also introduced the new multi-week forecasts available from September with global scope. He explained that there were user feedbacks from agriculture customers who need advanced warning for better crop management, not just the seasonal forecast of above average temperature. And this is one of many examples of operational decisions that are made in the sub-seasonal multi-week timeframes.

Dr. Gregory introduced some of the new products under development in conjunction with the customers and partners in emergency services and agriculture. He provided a few examples such as a seasonal forecast of rainfall extreme, a sub-seasonal (2^{nd} week) forecast of extreme heatwave, tropical weather, and fire weather. Other products such as forecast of fire season onset are under development.

Then, Dr. Gregory talked about the future plan and role of agencies such as BOM in changing climate. As the record-breaking weather becomes the new normal, he

provided a few examples of adaptation plan. Moving heavy plant equipment to the upper floor against future tides and having the entire building to be cyclone proof in inundation risk area could be examples of the significant engineering works to avoid future inundation from extreme events. Also, creating desalination plants for major Australian cities is one of the significant ongoing climate adaption examples.

Then, he explained what is needed in managing future climate risk. He pointed out that rapidly changing regulatory environment particularly from the finance and insurance is pushing for better estimates of future climate risk. Those sectors are now beginning to understand the risk of climate change to their balance sheets. As an example of global movement, he introduced the Task Force on Climate Related Financial Disclosure (TCFD) launched by Bank of England Governor in 2015 and chaired by Michael Bloomberg. Its goal is to develop consistent climate-related financial risk disclosures for use by companies in providing information to investors, lenders, insurers, and other stakeholders. Also, the Network for Greening the Financial System was created in 2017 and comprises 34 central banking institutions across five continents, which recently stated that it is "within the mandates of central banks and supervisors to ensure the financial system is resilient to [climate-related] risks." BOM is also talking to the energy sector, agriculture, federal and state government, defense, and regulators. The integrated risks are now well recognized and awareness is now raised in the broader community. But in some instances this awareness is just beginning. Also, people need to better understand the sources of uncertainty in the high resolution projections. Then, he provided what is needed for effective scenario planning: high resolution historical weather data; vulnerability, impact and exposure data; future scenarios and projections; knowledge brokers; and standardized methods.

Dr. Gregory finalized his talk by summarizing his presentations as current trends and emerging climate impacts in Australia, BOM's existing publically available climate products and services, BOM's new sub-seasonal products which provide earlier warnings of climate extremes to help operational decision making at multi-week timescales, examples of BOM's products which focus on extreme weather, and finally the growing need to provide high resolution scenarios of future extreme weather to all sectors of society.

14. **Mr. Jose Vicencio, Meteorologist of the National Weather Service of Chile (DMC), "Meteorological extreme events: From long-duration droughts to major floods"**

Mr. Jose Vicencio provided a review of main extreme weather events in Chile, particularly in last five years. He works in Climate Monitoring, assessing past weather events in the historical context. He explained that most meteorological values have extreme values. There are two main groups: 1) Fast and violent extremes (landslides, mud flood, forest fires, and tornadoes); and 2) slow extreme events such as droughts and heatwaves.

Due to its location, Chile is heavily exposed to changes in atmospheric circulations and changes in storm tracks at mid-latitudes. There are specific rainfall zones between

summer and winter rainfall regimes. Atacama gets 2 mm/year of rainfall and one weather station in the Atacama may have 1 rainfall event in 20 or 30 years. However, in March 2015, there was severe rainfall in the Atacama with more than 45 mm, which is 50 years of rainfall in a few days. The most impacted was the Atacama river basin. There were 31 deaths in three days due to the intense precipitation.

According to Rondanelli et al. (2019), a strong MJO event over Tropical Western Pacific created a wave train, and this wave (Rossby wave) propagated towards the pole and the east. A mixture of warmer-than-usual sea surface temperature at Chilean coast, high level of humidity, and a quasi-stationary upper-level low pressure triggered the devastating events such as high temperature in southern Chile and Antarctica and record temperature in Base Esperanza.

Mr. Vicencio then pointed out that the role of Dirección Meteorológica de Chile (DMC) is to forecast events, to analyse and contextualise, to describe, and to understand this extreme event to help prediction in the future. In 30-31 May 2019, tornadoes were recorded in southern Chile. DMC produced information which was reported in media about emerging tornado risk in Chile. Tornado in Concepción was recorded by Automatic Weather Station (AWS) and DMC team traveled to affected cities and determined that both tornadoes reached EF-1 and EF-2 intensity.

Also, he described that the trends in annual heatwaves are increasing. Summer of 2017 was very devastating with massive and unprecedented area of fires (500,000 square km), which is five times more than the previous recorded maximum, accompanied by all-time maximum temperature records. In Chile, it is very rare to have temperature above 40 due to the effect of Humbolt Current. During this time, 1/3 of cities reached recording temperature over 90th percentile. Therefore, they had to re-classify their fire rating, creating a category 6 on a 1-5 scale.

Central Chile experienced a big heatwave in February 2019 with 38.3^{o}C, an unprecedented temperature record in Santiago since 1860. Also, Tierra del Fuego reached over 30 ^{o}C, the first ever recorded temperature. There was mega-drought in central Chile where 80% of population live began in 2010 and still ongoing. This was strongly associated with a positive trend of SAM, and anomalies of high pressure at mid-latitudes (sub-tropical ridge). Using regional precipitation index, drought data from 2010 onwards is unprecedented. All inter-annual variability has been removed. And mega drought continues in winter of 2019. He pointed out the importance of maintaining and publishing historical data, particularly tornadoes which had been 'forgotten' in previous decades. Mr. Vicencio concluded his presentation by stating that DMC emphasizes the role in communicating extreme weather to general public via media in conjunction with scientific journals and papers.

15. **Dr. Jorge Carrasco, Research Associate of Antarctic Gaia Research Center, "Global Change in the southern-austral region of Chile and its impact in future climate"**

Dr. Jorge Carrasco provided a review of global change in southern-austral region of Chile and future impacts. He mentioned about climate drivers in Chile: westerlies and

sub-tropical storm tracks, with permanent high pressure cell in north of Chile sitting off Peru. Moist warm air during the summer can also be entrained from the Amazon. These systems move north and south during the year. Andes create significant orographic lift and rain on the Western side with a rain shadow east of the Andes. This provides different vegetation with evergreen and deciduous forests on the western sides and with steppe and magallanic forest on the eastern side. El Nino traditionally creates wet anomalies in Peru accompanied with increased westerlies and more storms during the winter at mid-latitudes. La Nina pushes the westerlies further south, creating wet anomalies towards Tierra del Fuego. Also, SAM influences southern Chilean rainfall.

Then, he raised a couple of questions that how SAM trends will change in the future, and if future changes would affect Pacific Decadal Oscillation (PDO) behavior.

Punta Arenas air temperatures are increasing, particularly in winter temperature, which is increasing faster than any other season. In past 100 years of monitoring, there has been significant decline in precipitation at Punta Arenas during last 20 years. This is because stronger westerly winds due to SAM cause more rain in past few decades on the westward (windward side) of Andes with corresponding decline on the Leeward (eastern side) of Andes. This led the decline in number of rainy days in Punta Arenas with decline of snow coverage of Brunswick Peninsula. Also, glacial retreat is observed throughout the Patagonian ice fields and glacial lake areas are increasing in Southern Patagonia. This brings the dangers of increasing Glacial Lake Outburst Floods (GLOF).

Dr. Carrasco mentioned that projections under RCP2.6 suggest a 0.5 degree of increase by 2100, and 5 degrees (particularly in mountain areas) under RCP8.5. Also, it is expected that there would be precipitation increases in far south and declines over the rest of Chile. That means more rain in the south and less snow. Also, it is predicted that drying trends would increase under RCP8.5

Dr. Carrasco concluded his presentation by stating that there is already enough research for making decisions and it is time for taking actions.

16. **Wrap-up and Discussion:**

The wrap-up and discussion session for session I was conducted for an hour with the session chair and five speakers stepping into the podium. Chair firstly stated that the session speakers mainly talked about extreme climate and its associated climate variability and predictability. Then he opened the Q&A and discussion to the floor.

There was a question regarding the predictability of decadal prediction. Dr. Kumar commented that the prediction skills come from ENSO, NAO, SST, etc. The main question would be how much the initialized prediction is provided in considering the predictability.

There was a series of questions regarding the different types of El Nino. It has been seen that the new kind of El Nino does now show the typical features from the traditional ones. For example, in Chile, if there is El Nino, it used to be anticipated to have a drought in coming months. However, recently this feature has not been seen.

And Prof. Yu commented that it has been seen that the El Nino shows changing characteristics. Then, a question regarding the impact of different kind of El Nino has been followed. The impacts of different types of El Nino to atmospheric responses are different, and the impacts need to be correctly predicted in order to predict the seasonal or decadal climate, which are affected by the changing El Nino. In order to improve the climate model, it is advised to firstly check where the deficiency lays in predicting zonal mean response. Also, there was a comment from Prof. Yu that the some El Nino is triggered by Australian Monsoon while traditionally El Nino controlled Monsoon.

Then, the speaker and audience talked about the national adaptation suggestion given there are much research and information provided and whether the vase information is enough for making future movement towards adapting climate change. Chair asked any suggestion or comment on enhancing the usability of climate information. Credible information is need more and at the same time, information needs to be tailored in usable form with close communication with users. Then, session chair concluded this session by appreciating all the speakers and participants for their active discussion.

Session II: Innovating Early Warning System to Manage Impacts of Climate Extremes

17. The morning session of August 21 commenced at 09:00. Session II discussed the key elements for developing early warning system and risk management to reduce adverse impact of climate extremes and how climate service-based early warning system is currently operated and implemented. The Session was chaired by Dr. Boksoon Myoung, Research Fellow of Climate Analytics Department, APEC Climate Center**.**

18. **Dr. Tim Manning, Senior Advisor of Pacific Disaster Center, "Shifting Hazards and Early Warning for a Changing Climate"**

Dr. Manning started by discussing what a changing climate means for a disaster manager. He noted that the issue could not only be seen as being about extreme events but that an effective response had to reflect a changing climate more generally. He said that the increase in the numbers of disasters, their severity, intensity and impact was related to many factors, including aging infrastructure and urbanization, and that climate change needed to be seen in that wider context. Dr. Manning noted that globally, hydro-meteorological events caused the largest category of disasters. In 2017, the majority of expenditure weather and climate induced disasters.

Dr. Manning noted that current disaster management planning and resourcing are often based on an analysis and understanding of past events. In a future that is changing rapidly, this model is likely to fail. He said that planning for the number of disasters and their magnitude based on the historical record model needs to change and that alongside this the communication of the risk to the public also needs to change.

Dr. Manning said that effective disaster management early warning is basically about communicating risk in a way that will get a real response from people. How do we communicate to both officials and the wider community about the changing risks and critically how do we communicate this changing risk to climate change doubters? Dr. Manning noted that "climate is what you expect, weather is what you get" and that whether or not people believe in an anthropological cause, it is undeniable that the climate is changing; the last 5 years were the hottest 5 years on record, according to both NOAA and UK Meteorological office data and the 12 lowest Arctic ice extent years have been last 12.

Dr. Manning said that current models for disaster risk reduction (DRR) are based on assumptions that are out-dated. The climate community needs to help communicate this and to provide updated assumptions and the base data that is used. Similarly, the public needs more effective and updated hazard-specific warnings that do not simply refer to historic recurrence intervals as probability base is clearly wrong and is changing. Warmer atmosphere, warmer oceans and shifting currents inevitably mean more rain and in new places. Historical hurricane tracks and the intensity of events

will change and rising sea levels will increase the base for storm surges, floods and expand the areas at risk.

Dr. Manning strongly argued that we needed to translate these wider messages for specific communities, for example what a 2-degree average global temperature rise means for New York. This level of specificity is needed for the critical first step of disaster management – identifying the threat – and when applied to disaster management planning to determine what resources, skills and teams are needed.

Dr. Manning concluded by noting that the public assessment of risk is rooted in memory. Our communication strategies needed to communicate why that is not adequate under changing climatic conditions. Early warning is now. We need to communicate that risk effectively to be the bridge between science and communities..

19. **Dr. Daeha Kim, Research Fellow of Climate Analytics Department, APEC Climate Center, "Overcoming the creeping nature of drought by tracking invisible energy fluxes"**

Dr. Kim said that there cannot be a simple universal definition of drought. A typical definition is often 'precipitation deficiency' but water deficits can be impacted by other factors and a strategy of only tracking precipitation is insufficient and impractical. Identifying communities that might be impacted needs process specifics indicating where and when and predicated upon climatology. Dr. Kim posed the question of whether a universal definition of drought was useful for early warning.

Dr. Kim noted that the perception that there were no solutions to drought meant that proactive risk management was essential. Early warning of precipitation deficits remained a challenge – there was high intermittency, high uncertainty and low predictability – so we therefore need to use other meteorological data-based indices. Dr. Kim suggested evapotranspiration (ET) anomalies could usefully be used as supplement precipitation information. There is a standardized ET deficit index (evaporative stress index) which represents actual and potential ET.

There is currently limited operational use of ET; for example, neither US nor European drought monitors currently use it and ET based indices are separated from major drought monitoring systems. Policymakers inevitably reflect "risk-averse" behaviour but the limited applicability of the current drought modelling with its high uncertainty, its ambiguity and its lack of clarity on locations and timing will inevitably limit mitigation and adaptation actions. Dr. Kim argued that ET could usefully be incorporated into operational models as is it could help deliver a monitoring system that was less uncertain and more predictable.

20. **Dr. Tzu-Yin Chang, Chief Team Leader of APEC Research Center for Typhoon and Society, "Risk Information Integration and Dissemination for Extreme Events"**

Dr. Chang set the scene by reflecting on three extreme events. The 2016 cold weather surge in Taipei (a 62-hour surge of the lowest temperatures recorded for the previous

44 years that caused extensive losses in fisheries and agriculture), Typhoon Soudelor in 2015 with rainfall of 253mm in 3 hours and a Tropical Depression in August 2018.
Dr. Chang spoke about the range of data that was increasingly available for decision makers. Various different data sources were available in each of the 4 stages of disaster management including social media. Managing these data sources and drawing the key information needed for decision makers was critical as was the integration of data types and the creation of simulation data for risk assessment. Models were needed for decision makers so they can understand the impact of extremes. Dr. Change reflected on the complexity of this process where more than 20 agencies were integrated, where the maintenance of over 200 real-time ongoing datasets was needed and where there was an interface more than 120 data types.
Dr. Chang noted that doing so provided the opportunity to deliver a range of products designed for different audiences and users. She spoke about the development of 'One Stop' alert platforms, the LINE@ Official Account through which warning information (including heavy rainfall, earthquake, low temperature, strong wind, air quality, etc.) is provided through customized subscription services and where the public can check the real-time warnings in Taiwan, and subscribe to receive real-time information on meteorology, hydrology, transportation, and livelihood information
Dr. Change concluded by noting that we needed to learn from extreme events to improve early warning systems, integrate various data to provide risk information for decision makers and that multiple channels needed to be used for delivering information to public to expand reach.

21. **Ms. Paola Uribe, Meteorologist of the National Weather Service of Chile (DMC), "The Warning System of Chilean National Weather Service"**

Ms. Uribe said that during last decade there had been many extreme events in Chile – flooding, river flooding, drought, flash flooding in Atacama, tornadoes. She noted that there were a series of International frameworks that support early warning – WMO member states commitment, Sendai Framework, Paris Agreement, and SDG goal 13 on climate change.
In 2012 DMC started using climatological thresholds to define extreme events of precipitation, temperature, wind velocity and gusts for Government offices. Ms. Uribe outlined the model used in Chile where short range forecasts, medium range forecasts, monitoring and dissemination lead through a robust process to alerts and warnings.
This was not enough information for effective disaster management so in 2014 changed to develop thresholds according to potential impact to develop EWS for precipitation, temperature and wind but extended to include forest fire forecasts.
Ms. Uribe noted that there had been a reanalysis of what was needed as a part of this to see how to improve as part of which there had been extensive consultation and surveys with the public (users). Some conclusions of that work on EWS were that a major user was education, followed by health then agriculture, mining and government. On timing (advanced warning) most people wanted/needed 1 to 2 days.

The analysis suggests that the public do not manage probability well as part of the messaging so DMC do not communicate probability. Warning system now needs to be dynamic and thresholds should change according to extreme events. New events need to be added such as extreme heatwaves and tornadoes. To improve EWS, radar system to be integrated as well as improved meteorological stations network, nowcasting, forecasting and meteorological models are important. A robust information network is important for dissemination of critical information to the public through social media – but is important that we can translate technical information into layman's terms and that it can be done so in a way that is aimed at the younger generations.

Ms. Uribe concluded by reflecting that EWS needs to be dynamic for changing climate. Human capacity development was critical for the improvement and maintenance of EWS. Effective EWS is one of the biggest challenges at the country level. Meteorological services would need to collaborate with citizens to understand what they want and to make it useful.

22. **Dr. Ashbindu Singh, President of Environmental Pulse Institute, "How Early Is Early Warning of Climate Extremes"**

Dr. Singh set the scene by describing an increasing world population but also increasing human development. Dr. Singh noted that natural disasters are increasing, and that hydrological events were affecting most people. 91% events from 1998 to 2017 had been climate related (mostly water related) and there was increasing evidence of increase in events due to climate change. These events affected vulnerable people most; floods and droughts particularly impacting low income groups while earthquakes affected middle income groups.

Dr. Singh said there were two basic components for combatting climate change strategies; mitigation and adaptation, but a third component, early warning, was needed to help people cope with extreme events (by providing timely, reliable and actionable warnings). The EWS need to respond to both slow onset and sudden impact extreme events.

Dr. Singh outlined the basic components of EWS: when & where, effective communication, strong network of institutions and an affected population able to receive and act on well formulated and actionable plans.

Dr. Singh then discussed how early EWS could be: tens of seconds for earthquakes, minutes for tornadoes, hours for tsunami, days and hours for volcanic eruptions, weeks and hours for hurricanes, 3-5 days floods (not flash floods which is minutes), months to weeks for droughts, and years or decades for slow onset threats (El Nino).

Dr. Singh noted that lead times were critical in EWS as well as reliable and fast communication, from authority to authority, and authority to citizens and from citizens to citizens. The gaps between early warning and action from warning were however not well understood; warnings were ignored or created no response. It was important that we invest in preparedness and mitigation focusing on disaster prone areas and the vulnerable. Timely alerts and actions can minimize impacts as long as

local communities are involved in communication and act on response through building capacity and resilience.

Dr. Singh concluded by saying that governments need to move from crisis based event management to preparedness. They needed to invest in science and technology for EWS and upgrade to latest tools; recognizing there were research challenges for EWS from precipitation. Communication needs to use all media and be actionable and reducing uncertainty leads to action.

23. **Wrap-up and Discussion:**

It is clear that many are still largely talking about single-event hazards despite a wider understanding that many of these are compound events that occur in sequence. There is a tendency not to think of compound events as a discrete whole but a sequence. Therefore, it needs to be considered to manage compound events. Response is still being done as if a series of discrete events. Therefore, it is suggested to understand how to communicate effectively without losing audience when talking about compound events. Hurricane Sandy was an example of such a compound event; with one dominant event taking all government attention. It is important not to get caught in a simple definition of one hazard or multi-hazard, as the response needed is the most important component. For example, Chile received flash floods, fires and heatwaves from same meteorological system, but in different areas.

Trust plays a big role in response. Climate forecasts are currently not within user trust sphere. Therefore, in gaining the trust from the public, it needs to tell people what to do, not only what the forecast is. Social science research will be important in doing so. People need to be able to take actions against forecasts, not only understanding what to do. The actionability of warnings is critical. Sending messages and communication to action currently only takes about 45% of what it could be – and this needs to be improved urgently.

Practical preparedness advice leaves out or is missing critical information. 3 days of food and water may not be sufficient when advising people that they need to get to higher ground and/or to go to areas where there is no shelter. Effective messaging to prevent mortality in acute phase - not only the comfort of survivors – is very important. Reducing risk involves big personal decisions, such as leaving your home, which is impacted by job security and many other equally important social phenomena. There are cultural differences that need to be taken into account in delivering effective messaging; no one size fits all, and trust in authority differs. Social science research does not currently integrate well with climatological/ meteorological science and its complex messaging and the same is true for disaster preparedness and management where social science is not integrated.

However it needs careful cautions not to try to reduce uncertainty beyond what the science tells us – climate is a complex issue as is climate change and shifting climate extremes. We need reliability and uncertainty to be communicated properly, not necessarily increased/decreased to create overly simple messages. What is biggest issue and how do we do are different things.

Usability is different to predictability. Slogans and images can portray wrong information. The usability of information needs to be improved. This has a strong sociological component. In doing so, it also needs to be aware that we may need to distance ourselves from what will be a politically charged environment. As a parallel it could be also considered that the scientific basis for rational decision making for evolutionists compared to creationists are unlikely to converge and therefore it would be better to separate from trying to communicate the science to communicating the impact and response options.

It is advised to learn from past experiences in response and communication. The potential impact needs to be at the forefront of the communication as that is how to gain trust. Close inter-sectoral collaboration will be important in developing the communications, and it is important to keep on the real tradeoff between what people should do and what they can do. Information and messaging needs to be kept practical and useful (getting under a desk in a nuclear attack is not a useful message). The bystander effect is also important to understand. If a fire alarm goes off, people look for reaction of the rest of the pack in order to react, and dealing with this phenomenon is a sociological issue that needs addressing. Understanding user communities is increasingly seen as an important issue, as is the education of children and conducting simulations to ingrain response mechanisms that last into adulthood.

Session III: Connecting Climate Information to Socio-Economic Values

24. The afternoon session of August 21 commenced at 14:00. In Session III, the five speakers discussed what is needed to promote socio-economic values of climate information, the roles of producers and end-users of climate services to facilitate better and more appropriate use of climate services for social and economic benefits, and the recent application of climate information. The session was chaired by Dr. Jeffrey K Lazo from Jeffrey K Lazo Consulting**.**

25. **Dr. Jin Ho Yoo, Director of Climate Services and Research Division, APEC Climate Center, "Tailoring climate information for better use : APCC's effort"**

Dr. Jin Ho Yoo addressed how the APEC Climate Center tailored climate information for better use. Sustainable growth is connected to climate change action. He noted that we are already experiencing periodic extremes similar to what will be much more frequent in the future.

Dr. Yoo said that each time we respond to climate variability, to an extreme event, it is a drill for longer-term climate change adaptation. CSIS (Climate Services Information System) is the most active component of GFCS which assists with provision of S2S information. Major NHMSs act as global producing centers and share seasonal predictions with CSIS. APCC is able to produce skillful predictions mostly in the tropics, where much of this is over the ocean. The overall HSS skill has gone up by 20-30% for this MME.

Despite this, Dr. Yoo asked why this information was not commonly used in decision making. He suggested that 1) the credibility of the information is low (perception of the meteorological service always being wrong); 2) the information is not relevant to decisions – people prefer to know how this year compares to last; 3) the information is not accessible enough or easy to find; and 4) institutional convention is not easy to change.

In responding to this analysis, he asked how we create early adopters of climate information and suggested that climate information must be tailored to the impacts expected given a certain change. In particular, he noted that climate information is coarse in spatial scale and the statistical information is not easy to parse. To address these issues, MMEs, statistical downscaling, impact assessment, and user-friendly interfaces are used. Application models require finer temporal scales, so APCC uses a multi-site probabilistic weather generator to simulate likely weather.

Dr. Yoo provided a series of examples of effective applications (e.g., the Pacific Islands Countries Advanced Seasonal Outlook (PICASO), Climate Information Toolkit (CLIK), a seasonal forecast downscaling tool, AIMS (APCC Integrated Modeling Solution) for climate projections, and CREAMS (Climate-Related Agricultural Risk Management System), a seasonal yield generator for agriculture) but noted that there are still real issues with tailoring the information derived from these applications. Information is distorted when downscaled (the global scale

information should drive the main "message" of the output), and impact models may add uncertainty (to be overcome with strategic communication and co-production).

Dr. Yoo summarised by noting that climate prediction (seasonal prediction) has settled down to become a key climate information source with some useful skill but that, in order to enhance the uptake of climate information in decision making, we need to transform (tailor) that information. The scales and form of information matter but in addition to the information's contents its credibility and valuation are critically important

26. **Dr. Sally J Edwards, Regional Advisor of Pan American Health Organization, "Extreme weather early warning systems: bridging the climate science – health divide"**

Dr. Sally Edwards spoke to climate services from the perspective of a health user. While natural disaster incidence is going up, global annual deaths from natural disasters are going down. Why, and is mortality the best metric for healthy living? Billion-dollar disaster events are going up. In the Americas, there have been many health-relevant extreme events including heat-waves, droughts, and vector-borne diseases. In Peru in April 2017 more than 650,000 people affected by an intense precipitation event, and while there were only 79 deaths, from a social point of view it was a huge issue that was not being properly dealt with. >145,000 homes were affected, as well as over 1,000 km of roads and 159 bridges – infrastructure that is critical for health. Often unseen the indirect effects of meteorological and climate extremes such as diseases are also important to note – not just deaths.

Multi-hazard early warning systems can help address this issue. We need to understand disease risk better, including the social component, and we must strengthen governance and connections. Climate early warning systems provide relevant and timely information, but EWSs for health are timely surveillance systems. These systems are not currently compatible as they use different terminology. Health systems need information with longer lead times.

WHO and WMO are developing climate services for health. They produce a climate and health bulletin regularly to interpret the information. This is important because the health community needs more context – not just the anomaly but what is normal. Currently extreme values are removed from climate normals used to produce climate predictions, but these extreme values are becoming more common. Dengue models and mosquito abundance models are built atop climate predictions. PAHO is focused on strengthening the resilience of health systems by developing EWSs. The WHO operational framework for climate resilience implements integrated risk monitoring and early warning. PAHO has also created action plans on climate and health that are available. One is available for the Caribbean and Central America and South America will be addressed next. PAHO also works with the WMO/WHO joint office to improve interdisciplinary connections.

27. **Prof. Hugo Romero Aravena, Associate Professor of Geography, University of Chile, "Urban climate information at the service of planning and management of the environment and sustainable development of Latin American cities"**

Dr. Hugo Romero Aravena began his remarks on the use of climate information in planning with a picture of Santiago - highly urbanized and populated but suffering from poor air quality. Urban areas are ecosystems with urban-scale biosphere, hydrosphere, etc. but we do not have an interdisciplinary approach to cities. Urban metabolism is essential to understand. Each physical feature of a city is producing environmental changes – so what is the role of climate change in terms of the future behaviour of our cities? How can climate information be infused into planning and into socio-political movements?

Cities are more interested in finance than in adapting to climate change. Urban Heat Islands and heat domes are central problems. We are not confronting air pollution in many Latin American cities because of the lack of wind – cities have been built to inadvertently restrict airflow. Buildings create specific microclimates, but we have never applied any assessment in our urban development process of these microclimates and we know very little about urban circulation patterns. Tall buildings along oceans such as in Panama City are interrupting airflow and sea breezes. Cities continue to build in wetland areas, ignoring climate information that could alert them to possible future flooding.

We need a multi-hazard strategy in urban planning. The poorest people are also the most affected in cities – so there is a lack of social justice. We need to address problems in community terms – consider shared identity, social networks, and local attachment – to build social capital. This information is informed with descriptive statistics for identity and attachment to places – and this must be integrated with climate/met information.

We need to move to co-produced information to empower the citizens. Urban sprawl is an issue in Santiago, which diminishes vegetation and increases heat in the city. We don't understand the development of Urban Heat Islands well enough. Yet there is no urban meteorological network in any city in Chile. Cultural values which prefer skyscrapers and other signs of modernity are encouraging UHIs. The climate of a city is a commodity – and areas with better urban climates cost more. In this year in Santiago, 3,500 people were killed by pollution. He asks why we design cities without consideration of climate.

28. **Prof. Sergio Radic Schilling, Director of Research, University of Chile, "Grasslands monitoring in Magallanes, a tool for farm planning as a socio-economic benefit for the Region"**

Prof. Sergio Radic Schilling addressed how his organization is supporting farmers with useful information from satellites to produce a dynamic monitoring system. They use high spatial resolution images from Feoeyes, Ikonos, and Worldview 2, as well as high temporal resolution information from MODIS every 16 days. They use NDVI,

LST, snow, potential evapotranspiration to compute pasture condition index (PCI) and Lifetime Value (LV). They use weather stations with solar panels which they have deployed to different parts of the region.

They present information like traffic lights per farm – red is bad and green is good. Farmers input information for ground truth. They have parameter ranges for each community of landscape – from valley greens through diddle dee, steppe, and grasslands. They also track animal movements between farms – to know when to move animals between winter and summer ranges. This must be timed correctly to prevent mortality. They use snow cover, NDVI, and knowledge of cold tolerance in sheep to determine a lower limit for safe moving. They also monitor changes in Hieracium polosella.

In response to a question from Dr. Jeffrey K Lazo, Professor Schilling confirmed that there was evidence that the people using these weather stations were seeing return on investment (ROI). As it was possible to estimate dynamic production people use it.

29. **Dr. Jeffrey K Lazo, Economist of Jeffrey K Lazo Consulting, "Economic Assessment of Hydro-Met Services and Products: A Value Chain Approach"**

Dr. Jeffrey K Lazo discussed the value of weather information. He started with Gunnison, Colorado, which he calls home. The winter 2017/18 period had one of the lowest snowfalls on record which hurt the ski industry and agriculture and led to summer wildfires. Then they had a record snowfall in winter 2018/19 causing flooding and filling reservoirs but giving great skiing. There were winners and loser from both events.

Weather extremes are the connection for most people to longer-term climate change. Thus weather information and its communication are important for climate communication. He noted that he used to pay less attention to climate change but as the impacts are becoming more visible, he is paying more attention. The book High Noon 2020 was referenced to show the prominence of global warming as an underlying issue – the social economic problem.

Economics is commonly applied for budgeting and program justification, and to help determine the value of NMHSs to user's goals. But it's also a study of human behaviour. He worked on a booklet on valuing weather and climate information available at WMO.org. Regardless of the method the return on investment (ROI) on climate information is positive, and in some cases produces very high returns. Economists use approaches such as Value of Information (VoI), but we have not done a good job measuring information quality. Economics has many methods for valuations including primary and secondary methods, and more primary studies are needed to support secondary.

Weather information can be considered as being developed along a value chain, which can be studied using economics. What happens in a disaster is a result of a set of historical facts such as socio-political forces leading to the economic outcomes. The information value chain helps to simplify weather information for economic analysis – essentially rendering complexity down to stakeholders that have objectives,

resources, and constraints. Other social sciences are just as important in understanding the value chain. Ex ante we can consider the value of information and ex post we can consider the impacts. The value chain has multiple stakeholders all along it that influences the chain. Economic methods are based on the outcomes such as morbidity/mortality, cost, etc. Dr. Lazo introduced a journal article of economic literature, "what do we learn from weather?" Economic data is a large constraint, but there is a lot of weather data available. From this weather information they did a study to find that every sector of the US economy is affected by weather and is sensitive to weather changes.

The value of weather forecasts is difficult due to a lack of counterfactuals. One study determined that the average value was some $286 per household. This is about $31bn per year. The value of improved forecasts was assessed in an NSF project using an in-depth mental model of the forecast system. They used this to analyse the value of providing information for evacuation decision making in hurricanes applying a stated preference method. They found that the cost of improving the accuracy of landfall forecasts from 50 to 25 miles to be some US$6.75 per household.

Dr. Lazo closed with some recommendations that do not just focus on extremes as day-to-day weather is also important, include behavioural economics, conduct more primary studies but make sure primary studies are useable for secondary, and benefits transfer studies. He added that all major investments in hydro-met services should include economic analysis, and thinking about the value chain helps get met service folks out of their met service box.

30. **Wrap-up and Discussion:**

The discussion after the five presentations started with a question if there is a study that has looked at VOI for climate service. Dr. Jeffrey K Lazo commented that if there was one it was modelling exercises of crop or hydro models without climate information. There has been little in the way of ex-post studies on climate. There are some applied studies on S2S for rain forecasts for agriculture but he is unaware of longer-term studies. The S2S studies have shown positive ROI – most have been for agriculture and energy. BOM with Deloitte did do an analysis on the value of climate information that can be shared.

Then, another question followed up: does the private sector have an indicator of the value of climate information? Dr. Lazo answered that the private sector has been proprietary with their information. Energy companies do bring in various forecasting companies and evaluate them and eliminate those that do not perform – this is useful for demand modelling.

There was a question to Prof. Hugo Romero Aravena that what we can do to encourage city planners and urban designers to integrate climate information into decision-making and planning. Prof. Aravena answered that the basic principles of urban design and climate have been introduced in curriculum, but the students do not like the constraints as they limit creativity. Thus there is a problem of different paradigms – designers want a blank slate – not a load of constraints to design in. We

are taught that the urban project is made for social equity, but for developers the city is a market. Younger architects and designers think in different terms. How do we put the architecture project, a building in a larger context? We need a multidisciplinary approach and downscaled information to the scale of decisions.

Then, there was a question whether WHO/PAHO climate and health program includes air quality. Dr. Sally Edwards answered that it is a part of the same program and, within the unit that is climate and environmental determinants of health where they do climate change, air pollution, and environmental epidemiology all together.

A series of questions regarding how to better develop climate and weather services for cities, how we hone advisories for an urban scale, and what it will take to do better were raised. Dr. Jeffrey Lazo commented that currently city forecasts are better than rural because radars are near airports which are near cities, and there may be a bias in forecasting for higher density places. National weather service do not forecast for specific end users – that is the private sector. The private sector is coming in and doing downscaling in ways that the weather service would not – even providing apps by city blocks. The US is moving toward very specific forecasts for specific users. Dr. Sally Edwards also responded by stating that it is country specific. The Caribbean for example has just one weather station as same for the Pacific Islands. It is not clear how to get that to a finer scale without losing information. Official weather stations are not easy to stand up because there are a lot of criteria. Also health data regions do not match with the meteorological regions, so it is difficult to compare apples with apples. The system needs to be examined holistically. Dr. Jin Ho Yoo also noted that the messages coming from government should be properly prepared for the city and be clear. Prof. Hugo Romero Arevena stated that the information at the city level is coming from the neighbourhoods. Each of these groups has very specific characteristics of urban morphology. Chile does not have networks at the city scale but they are going to arrange for meetings to improve observing networks in Chile. Urban groups also require an immediate answer to their questions. The construction of new infrastructure needs this information – the political need is clear. Thus the objectives to produce relevant information need to be clearly justified and shared. Society is becoming more concerned about climate change, and even preliminary results are making it to the front pages of newspapers. Dr. Lazo added that there is a movement to downscale the observing system – local radars, social media, and 3D printed weather stations – these can be built into the existing observing system.

Then, there was a question regarding EWSs. Who and what are the target of EWSs? Does one size fit all? The elderly are vulnerable and concentrated in certain parts of the city. There are many languages spoken in a city, which brings us back to risk communication. The ultimate EWS would be a tailored one based on urban morphology, for example. Dr. Lazo responded by providing an example of the hurricane Katrina. After Katrina people focused on intensity, but they realized they could not use information in 12 hours for evacuation – they needed 36 or more hours of warning because it was when they make decisions. Also different ethnic families have different evacuation ways based on culture.

Then, Dr. Lazo stated that typically warming systems are top-down and warning systems of the future might be organized by local communities being empowered to manage the problem with information coming in remotely. The bottom-up approach is empowering communities.

Prof. Aravena commented that the native populations living in Chile, particularly in the mountains, have their own EWSs by observing the environment. They observe the transparency of the sky to forecast rainfall. They all have local knowledge. The question is if our role is to test this knowledge. It differs from our scientific principles. They do not believe in climate change because the climate is always changing. They have been living in this place for 10,000 years and do not believe that they have anything to learn from scientists. As the natives move to cities they are bringing their belief systems with them. And it needs to be recognized that there are many beliefs to consider – this is an ethical question.

Dr. Sally Edwards commented that, regarding health, social mediating factors are extremely important. For the topic of dengue and how water is stored, social factors hugely mediate the issue so there needs to be more consideration than just top-down approaches.

Dr. Yoo added that the community also has to have a role, but the warning information needs to come from an authority in order to be taken seriously. Community action can be used to monitor and detect what is going on, and to develop local action plans.

Dr. Lazo raised a question that while short-term health impacts are studied, if there is any literature on long-term impacts. Dr. Edwards answered that disasters are such broad terms, but the drought in South America is chronic and there is clear correlation between dryer years, food insecurity, and developmental challenges of children in those communities. The long-term impacts are not taken as seriously as they should be since the focus tends to be on saving lives in the near term. First responders are also often neglected in considering impacts. Then, she added that different hazards require different early warning systems so there may be more room in some cases for a community approach. Prof. Glenn McGregor added that there are still great unknown areas regarding the cost of hospitalization for heat related illness, mental health issues after disaster, etc. Dr. Lazo commented that economics has an ethical structure that is open for discussion. And there is a large amount of health costing information – Kaiser Permanente has some and has looked into airborne toxics. The data is there but getting access is the challenge. Dr. Edwards commented that talking about mental health is still a taboo that people would not go to their clinical provider. Thus mental health issues are a latent cost driver because it underlies other maladies and missed work. Prof. McGregor added that people need to think about legal responsibilities in early warning systems. After the active discussion Dr. Lazo closed the Session III with his sincere gratitude to the speakers and the audience.

Session IV: Wrap-up, Panel Discussion, and Closing Ceremony

31. The Wrap-Up and Panel Discussion Session on August 22 commenced at 09:00. Each session was summarized by Dr. Seon-Tae Kim from the APEC Climate Center for Session I, Dr. Boksoon Myoung from the APEC Climate Center for Session II, and Dr. Sally Edwards from Pan American Health Organization for Session III.

32. For Session I entitled *Understanding of Extreme Climate Events and their Impacts*, Dr. Seontae Kim made a summarization of five talks. Dr. Arun Kumar provided a few definitions of extremes in the aspect of meteorology as well as societally relevant one. He also said that extremes can be correlated or compound, for example, hot and dry condition triggers bush fire and hot and moist condition triggers health danger. The societal impact of extreme events also depends on the characteristics of local climate. He then talked about the influence of changes in climate variability on extremes. Also in predicting climate extremes, links between modes of climate variability and local extremes can be used for the prediction of extremes. He finally provided utilization of WMO operational infrastructure for the extreme prediction. In the context of long-range forecasts, currently the most readily available information is change in the time-mean average and the probability of its occurrence. Based on historical data, this information can also be utilized to develop an outlook for the changes in local extremes. Prof. Jin-Yi Yu talked about the changing El Nino in the 21st century in terms of properties, dynamics, and impacts. He highlighted different type of El Nino which has been frequently occurred in the 21st Century. This is called Central Pacific (CP) El Nino. The 21st Century El Nino, so called Central Pacific El Nino, is more complicate to predict. CP El Nino produces different climate impacts in Asia-Pacific region than the 20th Century El Nino. As one possible reason for the change, the role of North Atlantic Ocean was proposed. Dr. Paul Gregory talked about forecasting of extreme weather events from sub-seasonal to decadal timescales. He provided examples of climatology of Australia and emerging issues such as sea level rise. For example, one of the most significant has been the reduction in rainfall over southern Australia during the cooler months while rainfall in Northern Australia during the wet season has increased. Also he introduced BOM's publically available climate products with global scale as well as new subseasonal products which will be opened soon. Mr. Jose Vicencio Veloso introduced major extreme weather events in Chile for the last five years. In March 2015, there was rain over Atacama Desert which caused 31 deaths. And at least two tornadoes were reported between May 30 and 31 2019 in Concepcion and Los Angeles. Historical tornadoes tend to form during autumn and mostly concentrated between Biobio and Los Lagos. He then showed an increasing trend in annual heatwaves and introduced mega-drought which is ongoing. He highlighted the role of DMC in extreme weather events in communicating with people about what is happening and how serious. The last talk was by Dr. Jorge Carrasco. He introduced atmospheric circulation and response which affect Chile. He also provided some local climate trend in Chile. The winter temperature of Punta Arenas is particularly increasing than any other season. And there is a decline of snow cover in Brunswick Peninsula. He also stated that there will be an increase in air temperature and precipitation in the Southern-austral region.

33. For Session II entitled *Innovating Early Warning System to Manage Impacts of Climate Extremes*, Dr. Boksoon Myoung provided a few wrap-up points of the presentations given throughout the session. Dr. Timothy Manning stated that disaster management has been based on understanding what happened in the past but disaster characteristics are changing rapidly with shifting climate, and therefore, traditional risk model approaches are likely to fail. And he pointed out that climate scientists need help communicating with others and updating assumptions and base data while public needs updated hazard-specific warnings. He stated the importance of translating messages for communities such as 'what dies 2-degree average global temperature rise mean for New York?' Communication strategies are needed to inform why memory-based response is not adequate under changing climatic conditions and he stressed the importance of bridging between science and communities. Dr. Daeha Kim stated that although drought is prolonged precipitation deficiency, precipitation-based early warning is a challenge – high uncertainty, low predictability, and lag times between complex land surface processes. Monitoring and declaration of droughts are not simple in nature. Therefore, it needs process specific indices indicating exact timing and locations for proactive drought risk management. Since evapotranspiration (ET) anomalies supplement precipitation anomalies, ET-based drought index (SEDI) is more process-specific, less uncertain and more effective for drought monitoring and early-warning. SEDI requires four variables (solar radiation, mean temperature, humidity and wind speed) but not precipitation. Dr. Tzu-Yin Chang stated that Taipei is very vulnerable to extreme weather events. She mentioned that integrated decision support system is developed for early earning and decision makers and there are various different data sources of disaster management including social media, and their integration and creation of risk simulation: CCTV images for better monitoring and evaluation, and risk models for decision makers to understand the impact of extremes. Also there is one stop alert platform integrating 6 different CAP alerts from 14 agencies and 13 layers. It provides not only risk information but also recommendations. She also mentioned that public can check real time warnings according to administrative areas. Cell broadcast service is also used to disseminate alerts such as natural, infrastructure and civil information warnings. She also said that multi-channels are used for delivering information to public to expand reach. Ms. Paola Uribe stated that during last decade, there were many extreme events in Chile – flooding, river flooding, drought, flash flooding in Atacama, and tornadoes. DMC started development of EWS based on International frameworks – WMO member states commitment, Sendai Framework, Paris Agreement, and SDG goal 13 on climate change. EWS used climatological thresholds and changed to impact-based thresholds. She introduced the public-users opinion poll on EWS as a good example in need of social studies. She also mentioned that new events need to be extended including extreme heatwaves and tornadoes. To improve EWS, it needs the improvement of meteorological stations network, nowcasting forecasts and meteorological models, information network for dissemination of information to the public through social media, and human capacity. EWS needs to be dynamic and thresholds should be changed according to updated extreme events under rapidly changing climate. She commented that meteorological services need to collaborate with citizens to understand what they want and to make it useful. Dr. Ashbindu Singh stated that there is evidence of increase in extreme events due to climate change. They affect vulnerable people

most; floods & droughts in low income groups and earthquakes in middle income groups. "How early is EWS" depends on events and lead time is critical. Gaps between early warning and action from the warning are not understood well, warning ignored, warning created no response, and therefore communication is the key. For typhoon/cyclone EWS, using satellite images people could see it coming and it made EWS most successful. For flood EWS, minimizing flood damage is critical to reduce fatality. For drought EWS, it is the most difficult phenomena as is slow onset. But response mechanisms are also effective in preventing deaths. It is important to invest in preparedness and mitigation for disaster prone areas and the vulnerable. Timely alerts and actions can minimize impacts as long as local communities are involved in communication. Governments need to move from crisis-based event management to preparedness. He also stressed that it is important to invest in science and technology for EWS and upgrade to latest tools and that **c**ommunication needs to use all possible media. Chair then highlighted comments during the discussion that in managing multi-hazards, 1) communicating with public without losing interests is important, 2) regardless of one hazard or multi-hazards, adequate response is important, and 3) integrated control by a disaster office essential is needed. For reliability in EWS it needs to tell people not only what the forecast is but also what to do. Also social science research is important as well as actionability of warning critical. Social science research has to be integrated with climatological/meteorological sciences as well as with disaster management. In facing climate change and shifting extremes and coping mechanisms, it needs to improve usability of information (rather than improve predictability only), needs to communicate the impact and response options rather than rational decision making that does not converge, needs to learn from the experiences of others to manage newly emerging hazards, and impact-based researches need to be at the forefront of communication and multi-sectoral/diciplinary environments. Close inter-sectoral collaboration for disaster management is important as well as keeping information practical and useful. Finally, educating user communities is important.

34. Session III entitled *Connecting Climate Information to Socio-Economic Values*, Dr. Sally Edwards pointed out that 5 speakers all looked at different applications of climate information, from APCC products, to health, to urban air pollution, to agriculture, and to economics. Although the range of topics was diverse, many similar themes emerged as following. The scale of the information is important. There can be a loss as climate information is downscaled, but without downscaling a lot of complementary information is missed – the example of air pollution in Santiago Chile was a key example about the need for a fine scale. The use of the information in decision making requires its refinement and tailoring. We need to understand the end user to be able to produce the information in the correct scale and to ensure that it is communicated the correct (most effective) way. The use of climate information should not only be top down (issuing alerts) but also bottom up. This depends on the type of event and there was discussion about recognizing the variance between the climatological definition of early warning systems and the broader user group definitions (animal and human health need not be from catastrophic climatological events). The intersectoral nature of the use of climate information should be emphasized. Human behaviour and social mediating factors are elements that influence not only the economics of climate change but also the health impacts (quick plug that it is not only mortality but

morbidity and general wellbeing that is important for health of humans and animals – heat stress has documented impacts in humans and animals). Climate projections do not necessarily need to be relooked at, but the application of the projections and the communication of the projections needs input from cross disciplinary teams. The long term impacts of climate are not well documented in any sector. There was a discussion of legal issues to do with the issuance of warnings, or rather the lack of warning resulting in economic and health impacts. To date no successful case has been tried in US but due to the way tort law works.

35. **Panel Discussion: Dr. Ashbindu Singh (Environmental Pulse Institute), Prof. Glenn McGregor (Durham University), Dr. Joy Shumake-Guillemot (WMO-WHO Joint Office), Dr. Jorge Carrasco (Antarctic Gaia Research Center), Dr. Tim Manning (Pacific Disaster Center), Dr. Jeffrey K Lazo (Jeffrey K Lazo Consulting)**

This panel discussion session was chaired by Dr. Ashbindu Singh. Before the discussion, Dr. Singh addressed key questions to tackle during the session: 1) how to enhance socio-economic usability to Climate Information Services to create sustainable adaption to Climate Change?; 2) how to reduce perception gaps in Disaster Risk Reduction (DRR)/Disaster Risk Management (DRM) sectors in Climate Information and what roles can scientists to promote communication amongst relevant sectors?; and 3) specific focus on how APEC member economies can benefit from enhanced climate information.

The panellist provided their insights and opinions on the first question. Dr. Tim Manning mentioned that APEC is a unique forum to discuss how to develop rational coherent decision since all the discussions would go up through various working groups to the leaders meetings in their final statements, which would be brought back to influence policymaking in each economy. Then, he stated that climate information plays a key role in Sustainable Development Goals (SDGs) and other goals (such as Sendai Framework). However, from DRR side of government and policy making in the US, climate information is only brought into policy when there is awareness and rarely an overt inclusion in broader issues.

Prof. Glenn McGregor stated that it is important to mount evidence from the increasing number of climate-related events and the economic impacts. The evidence between extremes and societal impacts can then be delivered to decision makers, and this requires integration of climate data with other data (such as economic and social data). He also pointed out that data and information are different and data is raw material which needs to be converted into information. For usability, the right type of information is needed as well as partnership with users and stakeholders to find out what information is needed. He also stressed a community of practice and partnership framework referring to the 'loading dock' analogue. Also there needs to be an evaluation of how successful early warning systems are in achieving their goals such as saving lives or preventing hospitalization.

Dr. Joy Shumake-Guillemot stated that there are some practical operational ways to enhance usability. Prioritizing your partnerships and getting your staff to attend urban

planning and national health dialogues would help contributing the scientific knowledge to the community. Also, inviting advisories from the community to your organization and evaluating the product life-cycle and the impact would be ways to demonstrate the value of the services. Also, to mainstream climate risk management and climate adaptation into economic policy, it must be more visible and therefore, it would be effective to allocating up to 20% of budget to the communications and to working on communication skills of the staff to translate the science. She also suggested integrating data system and providing open access of data to users. And she added strengthening the partnership with the allied sectors.

Dr. Jose Carrasco pointed out the general perception of forecasts has been improved recently and people recognize forecasts are good to make decisions on a daily basis. Climate prediction had not had such positive perception, but with the communication of ENSO effect in Chilean climate, it has gained community trust gradually. Also, recent experience of extremes has raised trust as well. He pointed out people started to believe the information, but the issue is how to make is more useful. He suggested authorities possibly reinforce the importance of prediction in the context of current extremes.

Dr. Jeffrey Lazo commented that, as an economist point of view, the reason why people do not respond to the existential threat of climate change is the public has more uncertainty than the climate scientists have. And he introduced an economic idea of discounting that while there would be billion dollar impact in 100 years and it would only cost $70,000 now, people would not spend money now for the later impact. But he also stressed that this is not the remote future impact but the immediate future. He also mentioned the concept of free riding that people think to get a free ride if everyone else cuts their emission, and such paradigm needs to be changed. The solution depends on how the problem is framing. And the question of usability of information for policy is not a simple one and it has to be different question and approach for public and private sectors.

Dr. Manning commented that how to communicate to which audience is a big part to improve the usability and, based on his experience with policy makers, the effective public communications indirectly connects to the policy makers. The policy makers are reluctant to make unpopular decisions and therefore he suggested brining the policy makers along when speaking to the public. Also, he pointed out that scientist is reluctant to pin down on precision and needs to be more confident with uncertainty. He suggested carefully considering the outcome message, for example phrasing ‘you area will flood in next 20 years’ instead of using the term of return period. Also, he stressed the value of inter-disciplinary work. Climate community and APCC need to recommend joint events with disaster working groups or health working groups. APEC is the most vulnerable community where sea level rises and economies and communities are already disappearing.

There was a comment from the audience which recognized the importance of social science and economists. He shared the experience of recent project working with small farmers. And it was surprising to see that the farmers understood risks but do not know how the products (from NHMSs) could affect their risk analysis. Therefore,

it needs to be a paradigm shift in Meteorological centers in working with evaluation, training modules, and products that are usable to communities.

Dr. Lazo then pointed out that there are different types of economists and communication person and that the meteorological services and agencies first need to understand what type of economics is needed.

Prof. Hugo Romero from the audience commented scientific knowledge is not well transmitted to society, but fake news is directing social activity. And he talked about the importance of having clear message to communicate, placing the science in the broader society, interpreting the feel of the people, and focusing on the common everyday life in communicating with the public and improving usability of climate information.

Dr. Lazo also mentioned that the primary source of scientific information for many people is their weather TV broadcaster. Some US groups of meteorologists are providing materials to broadcast the routine local climate information. This neutral voice has shown to have a positive impact in terms of climate understanding. And this is one avenue to climate usability.

Dr. Ashbindu Singh stated that while climate change is now central to development and SDGs of many economies and communities, many NHMSs are not involved in the creation of policy documents. And he also suggested APCC works for putting science to the national plan such as Intended Nationally Determined Contributions (INDC).

Dr. Manning mentioned that the international meetings such as UN platform meetings or APEC meetings have helped facilitate combining internal politics and ministries and break down national bureaucratic walls. He also pointed out that while meteorological agencies are small they constantly are challenged for capacity development and product sharing and having peers that provide an example helps establish a case back home. Dr. Lazo agreed that the climate problem is helping meteorological agency development.

Dr. Jorge Carrasco also commented that in Chile, the NHMS has two branches; weather and climate/applied meteorology. It used to be all concentrated in weather services and it was difficult to push climate services within Dirección Meteorológica de Chile (DMC). However, climate information and services became important when WMO created idea of GFCS (Global Framework on Climate Services) and DMC could promote climate services.

Dr. Ashbindu Singh then asked the panelist how to get climate information to the related sectors and ministries while it is impossible to deal with all the sectors such as agriculture, forestry, health, tourism, etc.

Prof. McGregor stated that much of the public still do not understand the distinction between weather and climate. To strengthen climate services in the government, it needs to push the difference between weather and climate services. The public would appreciate understanding these differences. Dr. Lazo then commented that the public's perception of predictability is based on weather, not climate and that climate is often more predictable.

There was a comment from the audience that Chinese Taipei started to assess risks to transport infrastructure such as sea level rise: damage from ocean to coastal highway will increase and airports are vulnerable. Central Weather Bureau supplied data to transport department and conducted assessment on how the weather and climate information is used. He also stated that while dissemination channels have generational difference the 1st platform to receive information is through TV.

Dr. Carrasco stated that education is the key in bridging the gaps. Dr. Shumake-Guillemot also commented on how to reduce perception issues which are deeply rooted in social values. She recommended hiring social scientists and engaging the universities with the task to figure out how to reduce perception gaps. Then the NHMSs and related organizations could start developing action plans. She also noted that most agencies do not have strategic plans to enhance utilization of the services. She shared one example by mentioning that 10 years ago WMO launched GFCS but had no expertise in health and they reached out to WHO. Dr. Sally Edwards was within the regional arm of PAHO and attended the Caribbean Regional Climate Outlook Forum (RCOF) to bring NMHSs and Health ministries together. These are the steps required to help change perceptions. And she also said that attending Climate Service conferences driven by user communities is a good opportunity.

There were comments from the audience. Dr. Hen-I Lin shared his experience of working with Central Weather Bureau in Chinese Taipei since 2012 and stated that CWB has subsequently invested in their own climate services and central government is increasing their funding over the past two years. A representative from PAGASA shared her experience that at the monthly climate forums held by PAGASA, the users present how they use the information. PAGASA also has established climate field schools including agriculture extension workers. Dr. Won-Tae Kwon form APCC shared her experience of leading climate research laboratory in the Republic of Korea 15 years ago and frustration with lack of user feedback, which eventually helped developing Korean Society of Climate Change Research.

Dr. Lazo mentioned the case of NCAR (National Center for Atmospheric Research) in the US tying to demonstrate the possible applications of climate science and information with end users. Dr. Shumake-Guillemot added the value of embedding multi-disciplinary scientists in understanding what the needs are.

Dr. Manning suggested the economies explore their requirements for climate information to drive the agenda. He also stated that there are a few climate scientists in national DRR agencies. They need translation of 'what it means'. For sustainable growth, it would be helpful to highlighting the impacts, for example that high tides mean the coast is abandoned. And he stressed that all DRR and mitigation are based on potential future models and climate change models need to be reflected. Dr. Carrasco added that since people understand personal impacts well it would be helpful to talk about climate change impacts at a personal level. Prof. McGregor suggested tailoring information to a specific potential disaster in DRR planning as well as transforming data into information particularly for specific region or economy.

Dr. Singh provided a recommendation to APCC to be involved in regional economies to link the climate science with policy directly. Dr. Shumake-Guillemot also stressed the importance of moving towards cohesive policy framework.
Finally, Dr. Singh closed the Panel Discussion by thanking all panellists and participants for their contributions

36. Dr. Won-Tae Kwon, Executive Director of the APEC Climate Center, concluded the symposium with a speech highlighting the importance of productive discussion and impressive progress regarding extreme climate events and its management shown during the symposium to achieve sustainable development. Also she thanked the co-hosts of the event and organizing team for their hard work. Dr. Enrique Garrido Segovia, Deputy Director of National Weather Service of Chile, then gave a speech to reemphasize the importance of the fruitful presentations and discussions to improve the knowledge and methodologies to cope with the challenges of changing climate. And he thanked all the speakers and participants for their active participations and interests on making APCS 2019 as a successful event. After this, the symposium came to a close.

ANNEX: APEC Climate Symposium 2019 Participants List

No.	APEC Economy	Name	Affiliation	Gender
1	Australia	Paul Gregory	Bureau of Meteorology	M
2	Chile	Jorge Carrasco	Antarctic Gaia Research Center	M
3	Chile	Marcelo Leppe	Chilean Antarctic Institute	M
4	Chile	Canobra Miranda Marcelo	Chilean Antarctic Institute	M
5	Chile	Salgado Maria Jose	Chilean Antarctic Institute	M
6	Chile	Valledare Marangunic Carlos	Chilean Antarctic Institute	M
7	Chile	Vasquez Juan	Chilean Antarctic Institute	M
8	Chile	Velasco Rodrigo	Chilean Antarctic Institute	M
9	Chile	Claudio Radonich Jimenez	City of Punta Arenas	M
10	Chile	Enrique Garrido Segovia	Direccion Meteorologica de Chile	M
11	Chile	Jose Vicencio	Direccion Meteorologica de Chile	M
12	Chile	Paola Uribe	Direccion Meteorologica de Chile	F
13	Chile	Gaston Torres	Direccion Meteorologica de Chile	M
14	Chile	Rodrigo Arnaldo Padilla Torres	Direccion Meteorologica de Chile	M
15	Chile	Diego Alvaro Campos Diaz	Direccion Meteorologica de Chile	M
16	Chile	Ricardo Antonio Vasquez	Direccion Meteorologica de Chile	M
17	Chile	Maria Carolina Vidal Guajardo	Direccion Meteorologica de Chile	M
18	Chile	Vera Beatriz	Directorate General of Civil Aviation	F
19	Chile	Celedon Teresa	GORE Magallanes	F
20	Chile	Andrade Sanchez Christian	Government of Chile	M
21	Chile	Bernal Andres	Government of Chile	M
22	Chile	Canales Reiner	Government of Chile	M
23	Chile	Casanova Pino Edgardo	Government of Chile	M
24	Chile	Diaz Cesar	Government of Chile	M
25	Chile	Errecalde Adriana	Government of Chile	F
26	Chile	Fernandez Dubrock Rodrigo	Government of Chile	M
27	Chile	Gonzalez Rita	Government of Chile	F

28	Chile	Gonzalez Nidia	Government of Chile	F
29	Chile	Gorziglia Carlo	Government of Chile	M
30	Chile	Guerra Elsa	Government of Chile	F
31	Chile	Hebel Ingrid	Government of Chile	F
32	Chile	Jaña Ricardo	Government of Chile	M
33	Chile	Kubota Cifuentes Cristian	Government of Chile	M
34	Chile	Mansilla Muñoz Andres	Government of Chile	M
35	Chile	Paulsen Nicolas	Government of Chile	M
36	Chile	Pelembe Eduardo	Government of Chile	M
37	Chile	Perez Claudio	Government of Chile	F
38	Chile	Quelin Javiera	Government of Chile	F
39	Chile	Rees Jones John	Government of Chile	M
40	Chile	Retamales Jose	Government of Chile	M
41	Chile	Riffo Fideli Jose	Government of Chile	M
42	Chile	Rodriguez Milithza	Government of Chile	M
43	Chile	Suarez Navarro Angel	Government of Chile	F
44	Chile	Trvisan Cristine	Government of Chile	F
45	Chile	Vargas Espinoza Priscila	Government of Chile	F
46	Chile	Vega Artigues Edgardo	Government of Chile	M
47	Chile	Alejandro Soto Bórquez	Government of Chile	M
48	Chile	Ana Mayorga Bahamonde	Government of Chile	F
49	Chile	Ca. Don Ronald Baasch Barberis	Government of Chile	M
50	Chile	Carlos Bianchi Chelech	Government of Chile	M
51	Chile	Carolina Goic Boroevic	Government of Chile	F
52	Chile	Claudio Villarroel Buxton	Government of Chile	M
53	Chile	Fabiola Garcia Pinto	Government of Chile	F
54	Chile	Gabriel Boric Font	Government of Chile	M
55	Chile	Gba. Don Eduardo	Government of Chile	M

		Mosqueira Cruz		
56	Chile	Gdb. Don Jorge Peña Nuñez	Government of Chile	M
57	Chile	Hernan Soto Muñoz	Government of Chile	M
58	Chile	Homero Villegas Nuñez	Government of Chile	M
59	Chile	John Rees Jones	Government of Chile	M
60	Chile	Karim Bianchi Retamales	Government of Chile	M
61	Chile	Katherine Ibacache Calderón	Government of Chile	F
62	Chile	Lil Andrea Garcés Eyraud	Government of Chile	M
63	Chile	Liz Casanueva Méndez	Government of Chile	F
64	Chile	Luis José Godoy González	Government of Chile	M
65	Chile	Marcelo Canobra Miranda	Government of Chile	M
66	Chile	Marco Antonio Mella Borquez	Government of Chile	M
67	Chile	Margarita Norambuena Caviedes	Government of Chile	F
68	Chile	María Soledad Solo De Zaldivar Estefó	Government of Chile	F
69	Chile	Mariela Rojas Ramirez	Government of Chile	F
70	Chile	Matías Vieira Guevara	Government of Chile	F
71	Chile	Nelson Cárcamo Barrera	Government of Chile	M
72	Chile	Pablo Rendoll Balich	Government of Chile	M
73	Chile	Patricia Mackenney Schmauk	Government of Chile	F
74	Chile	Paulina Barraza	Government of Chile	F
75	Chile	Ricardo Ritter Rodríguez	Government of Chile	M
76	Chile	Rudi Mijac Kusanovic	Government of Chile	M
77	Chile	Safira Ivelic Gallardo	Government of Chile	F
78	Chile	Sandra Amar Mancilla	Government of Chile	F
79	Chile	Soto Volkart Nicolas	Ministry of Defence	M

80	Chile	Rebolledo Manriquez Lorena	Municipal	F
81	Chile	José Fernández Dübrock	Region of Magallanes	M
82	Chile	Alejandra Muñoz Quiroz	Secretarias Regionales Ministeriales de Salud(SEREMI)	F
83	Chile	Alfonso Roux Pittet	Secretarias Regionales Ministeriales de Salud(SEREMI) de Agriculture	M
84	Chile	Francisca Rojas Philippi	Secretarias Regionales Ministeriales de Salud(SEREMI) de Bienes Nacionales	F
85	Chile	Beatriz Sanchez Cañete	Secretarias Regionales Ministeriales de Salud(SEREMI) de Educacion	F
86	Chile	Fabian Mella Olivos	Secretarias Regionales Ministeriales de Salud(SEREMI) de Justicia	M
87	Chile	Eduardo Schiappacasse Dasati	Secretarias Regionales Ministeriales de Salud(SEREMI) de Medio Ambiente	M
88	Chile	Carlos Quezada Aliste	Secretarias Regionales Ministeriales de Salud(SEREMI) de Mineria	M
89	Chile	José Miguel Horcos Guarachi	Secretarias Regionales Ministeriales de Salud(SEREMI) de Vivienda y Urbanismo	M
90	Chile	Hugo Romero	University of Chile	M
91	Chile	Juan Oyarzo Pérez	University of Magallanes	M
92	Chile	Sergio Radic Schilling	University of Magallanes	M
93	Chile	Barrios Rojas Carmen	University of Magallanes	F
94	Chile	Huenucoy Carolina	University of Magallanes	F
95	Chile	Quelin Montaña Javier	University of Magallanes	M
96	China	WU Huanping	China Meteorological Administration	M
97	India	Ashbindu Singh	Environmental Pulse Institute	M
98	Indonesia	Muhammad Agung Fauzi	Indonesian Meteorological Climatological and Geophysical Agency	M
99	Indonesia	Nelly Florida Riama	Indonesian Meteorological Climatological and Geophysical Agency	F
100	Japan	Takayuki Tokuhiro	Japan Meteorological Agency	M
101	Korea	Hwanil Park	Science and Technology Policy Institute	M
102	Korea	Sohyun Kwon	Science and Technology Policy Institute	F
103	Korea	Won-Tae Kwon	APEC Climate Center	F
104	Korea	Jin Ho Yoo	APEC Climate Center	M

105	Korea	Sangwon Moon	APEC Climate Center	F
106	Korea	Seontae Kim	APEC Climate Center	M
107	Korea	Boksoon Myoung	APEC Climate Center	F
108	Korea	Daeha Kim	APEC Climate Center	M
109	Korea	Suhee Han	APEC Climate Center	F
110	Korea	Inja Jeon	APEC Climate Center	F
111	Malaysia	Khazainani Salleh	Malaysia Meteorological Department	F
112	Malaysia	HAFIZA HASSAN	Ministry of Energy, Science, Technology, Environment and Climate Change	F
113	Malaysia	Abdul Aziz bin Mahamad Zabidin	National Disaster Management Center	M
114	New Zealand	Brett Mullan	National Institute of Water and Atmospheric Research	M
115	Peru	Gustavo De La Cruz Montalvo	National Service of Meteorology and Hydrology	M
116	Philippines	Rosalina De Guzman	Philippine Atmospheric, Geophysical and Astronomical Services Administration	F
117	Philippines	Thelma A. Cinco	Philippine Atmospheric, Geophysical and Astronomical Services Administration	F
118	PNG	Kasis Inape	National Weather Service	M
119	PNG	Immanuel Erick Sarut	Climate Change and Development Authority	M
120	Chinese Taipei	Tzu-Yin Chang	APEC Research Center for Typhoon and Society	F
121	Chinese Taipei	Yeu-Woo Lin	Central Weather Bureau	M
122	Chinese Taipei	Ming-Ying Lee	Central Weather Bureau	M
123	Chinese Taipei	Hen-I Lin	Chung-Hua Institution for Economic Research	M
124	Thailand	Maytee Mahayosanunta	Thailand Meteorological Department	M
125	Thailand	Chalump Oonariya	Thailand Meteorological Department	M
126	Thailand	Tanat Tanaboon	Thailand Meteorological Department	M
127	UK	Glenn McGregor	Durham University	M
128	UK	Sally J Edwards	Pan American Health Organization	F
129	USA	Joy Shumake-Guillemot	WHO-WMO Joint Office for Climate and Health, WMO	F
130	USA	Arun Kumar	CPC/NCEP/NWS/NOAA	M

131	USA	Jin-Yi Yu	University of California, Irvine	M
132	USA	Tim Manning	Pacific Disaster Center	M
133	USA	Jeffrey Lazo	Jeffrey K Lazo Consulting	M
134	USA	Hunter Jones	National Oceanic and Atmospheric Administration	M
135	Viet Nam	Le Thanh Hai	Viet Nam Meteorological and Hydrological Administration	M