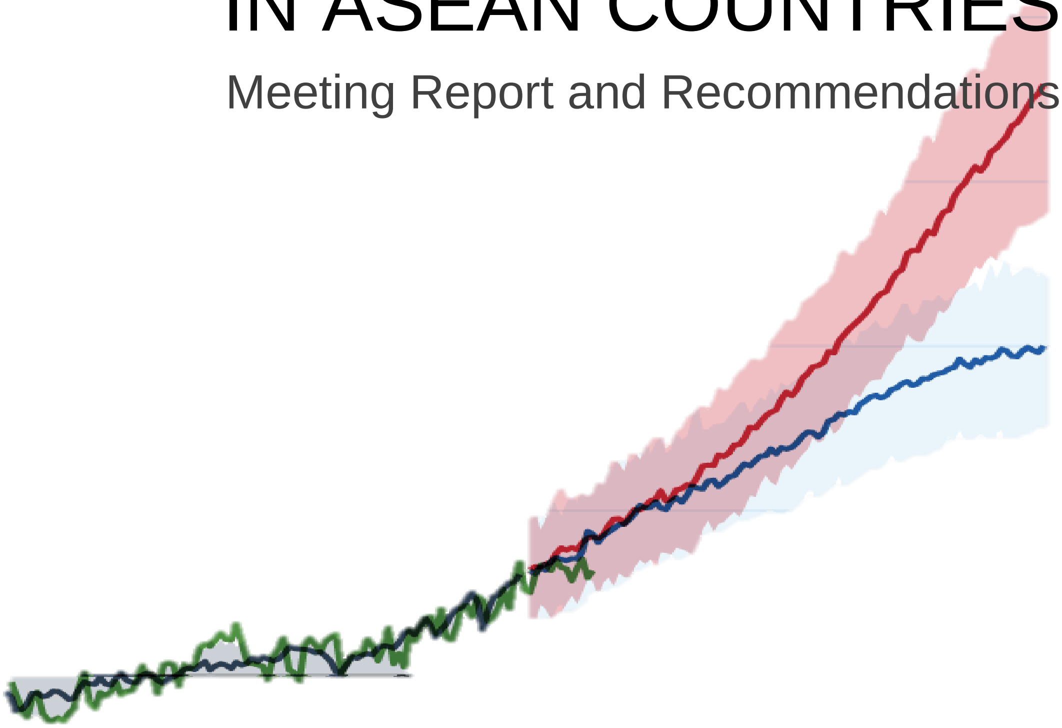
BEST PRACTICE WORKSHOP ON CLIMATE CHANGE PROJECTIONS AND THEIR APPLICATIONS IN ASEAN COUNTRIES

Meeting Report and Recommendations



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Participants to the

"Best Practice Workshop on Climate Change Projections and their Applications in ASEAN Countries"

20th – 23rd March 2018

Singapore

Table of Contents

1 Background and Overview of Workshop Objectives

The Association of Southeast Asian Nations (ASEAN), comprising Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam, lie in Southeast Asia, a region sensitive to climate variability and change. In the last decade, most countries in the region have developed climate change projections to support national adaptation plans in response to concerns expressed by governments. The projections from these studies, which are conducted at the national level via top-down processes, have a lot in common from one ASEAN country to the next. Therefore, improving coordination and sharing of experience between countries in the region would help develop regionally relevant best practice guidelines.

In recognition of the above, the WMO RA V Working Group on Climate Services (WG-CLS), in early 2016, proposed a workshop to review climate scenarios for the region, as well as the methodologies and challenges in their use in impact studies and adaptation policies.

The relevance of the proposed workshop was further demonstrated by a survey completed in 2017 on “Climate Information and Services” across the National Meteorological and Hydrological Services (NMHSs) of Southeast Asia and conducted by the ASEAN Specialised Meteorological Centre (ASMC). The survey confirms that while regional NMHSs have the mandate to provide climate products and services in their countries, their organisations’ visibility is not optimal in an environment where other private or commercial entities provide alternatives to end users. As part of the survey, “downscaled global climate change projections” is consistently listed amongst the important products in need of capacity development. The survey also highlights the usefulness of relying upon NMHSs which have well-developed interactions with local users and stakeholders.

To conduct this workshop, it was proposed to consider Southeast Asia as a whole, since at present the ASEAN region includes countries in both RA V and RA II. This is an appropriate arrangement considering the common climatological features of the region and it follows previous and existing initiatives to coordinate regional climate change projection efforts, such as:

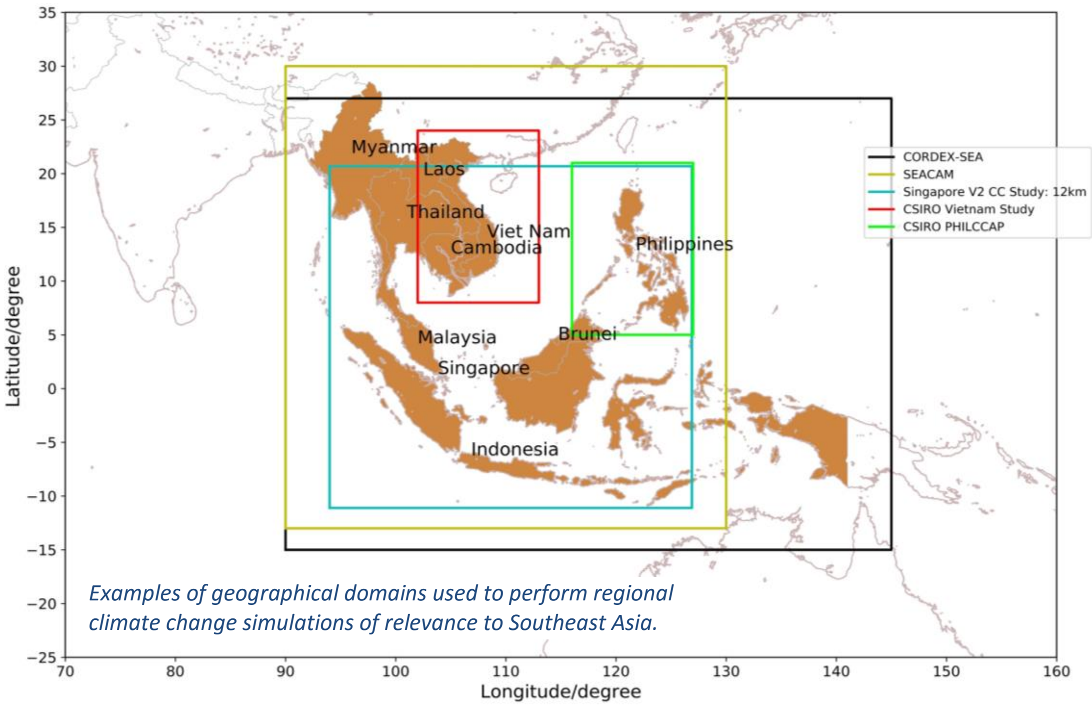
- Southeast Asia Climate Analysis and Modelling (SEACAM), initiated and funded in 2011 by Singapore with technical support from UK Met Office Hadley Centre. SEACAM’s objectives were to enhance regional scientific cooperation and increase scientific capacity among climate researchers in the Southeast Asia region. The project made use of high resolution regional simulations (25 km) using a single Regional Climate Model (RCM): the UK Met Office’s PRECIS model forced with Coupled Model Intercomparison Project (CMIP3) Global Climate Models (GCMs).
- Southeast Asia Regional Climate Downscaling (SEACLID), established as a collaborative project in regional climate downscaling with collaborators from various countries within the Southeast Asia region. SEACLID has been streamlined and integrated into the World Climate Research Programme (WCRP)'s Coordinated Regional Climate Downscaling EXperiment (CORDEX) and renamed as SEACLID/CORDEX Southeast Asia (CORDEX-SEA). SEACLID/CORDEX-SEA is downscaling a number of CMIP5 GCMs for the Southeast Asia region to a resolution of 25 km through a task-sharing basis among the institutions and countries involved. It represents a step forward as several regional models are used, allowing a more comprehensive description of the uncertainties attached to regional climate change projections.

These coordinated programmes produce regional climate projections by using RCMs to downscale GCMs made available by the international research community through the CMIP programme. The latter programme is in support of the Intergovernmental Panel on Climate Change (IPCC) and its mandate to deliver regular climate change assessment reports. The climate projection scenarios provide future ranges of quantities such as temperature, rainfall, wind, and sea level rise from which national agencies can develop Vulnerability Impact Assessment (VIA) studies.

In addition to these regional coordination attempts, other climate services and RCMs simulations are also performed in support of national initiatives, such as:

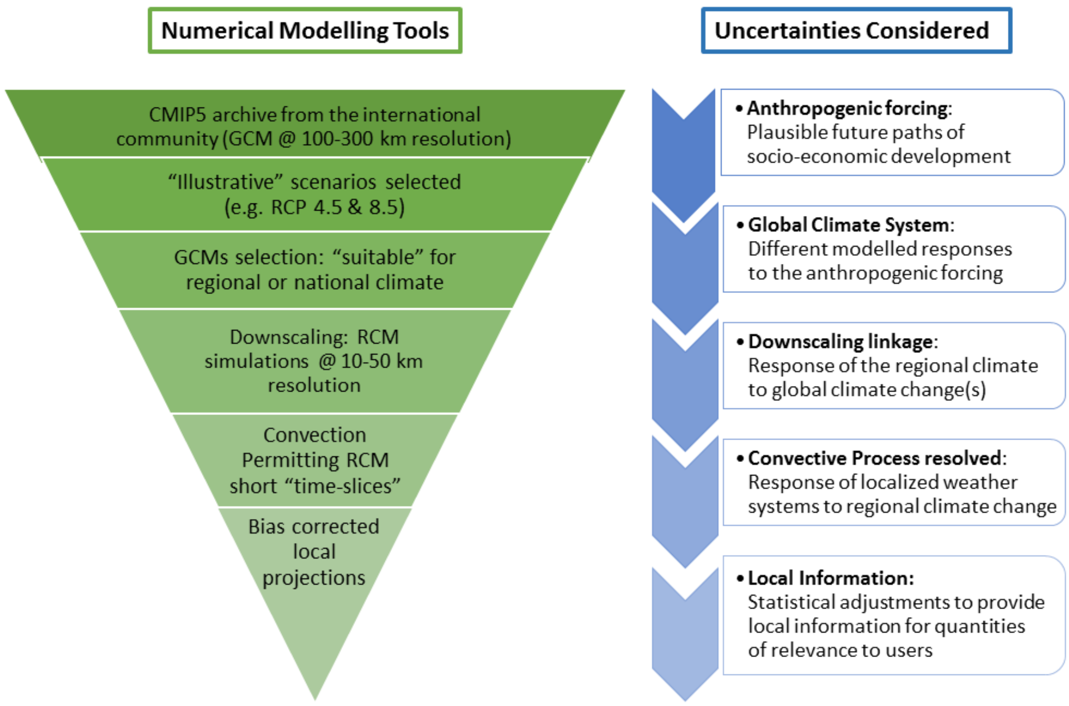
- The Regional Climate Projections Consortium and Data Facility (RCCDF) was started in 2015 by Australia CSIRO and supported by the Asian Development Bank (ADB). It relies primarily on regional climate change projections obtained with the CSIRO's CCAM model used at high resolution around Southeast Asia and forced with CMIP5 GCMs. 3 ASEAN countries, Indonesia, Thailand and the Philippines, were involved in this programme.
- Downscaling experiments (to 25 km resolution) over the Southeast Asian region using the CCAM model were conducted under the PhilCCAP project, a collaboration between CSIRO, PAGASA and UKMO. CSIRO also collaborated with the Institute of Meteorology, Hydrology and Environment, Vietnam (IMHEN) and the University of Hanoi to generate high-resolution (10 km) downscaled projections over Vietnam using the CCAM model.
- Singapore's 2nd national Climate Change Projection study (V2), which was based upon the UK Met Office's PRECIS V2 model forced by 9 CMIP5 GCMs, and run with a resolution of 12 km.

Despite the fact that the various regional studies share a number of commonalities, for example RCM resolution and spatial domain (see figure below), to date no attempt has been made to compare and contrast the various supra-national studies emanating from a regional coordination perspective with the national studies emanating from a national perspective.



Examples of geographical domains used to perform regional climate change simulations of relevance to Southeast Asia.

Considering the large uncertainties inherent in climate projections, improved coordination would be highly valuable in providing a complete estimation of the potential risks posed by climate change. A full uncertainty estimate across GCMS projections and using various RCM downscaling is prohibitive for very high resolution simulations required to provide more realistic and locally relevant information (as illustrated in the next figure). Furthermore, the establishment of best practices on how to represent these uncertainties in downstream impacts is also not straightforward and has not been comprehensively developed across Southeast Asia.



Schematic illustrating the modelling tools relied upon to deliver typical national climate change projections (left) and the uncertainties considered (right) as finer numerical modelling tool are relied upon (source: "Generating Climate Change Rainfall Scenarios for Singapore; A Tale of Scale", Hassim et al., COSMOS Research Highlights, 2017).

The benefit of regional coordination across ASEAN NMHSs is now well-established in the delivery of climate services for sub-seasonal to seasonal time-scales. This takes place via the regular Regional Climate Outlook Forum (ASEANCOF), in which relevant scientific methodologies and experiences are shared amongst NMHSs as well as regional end-users.

The proposed workshop was modelled after the ASEANCOF, with a similar aim of facilitating knowledge exchange amongst the ASEAN community, but with a focus on defining best practice recommendations for the production of climate change projections and their application by end-users.

During the development of the concept for this workshop, it was recognised neighbouring countries from the Southwest Pacific regions were dealing with similar issues. With the support from Australian scientists (from the Bureau of Meteorology and CSIRO) as well as regional partners (such as the Secretariat of the Pacific Regional Environment Programme, SPREP), the workshop presented an opportunity to establish a bridge between the two regions and leverage upon a wider range of perspectives and collaborative strategies.

In light of these background elements, the main workshop objectives were to:

- Conduct a comprehensive stocktake of national climate change projection studies completed across ASEAN and through the various regional coordination efforts (in particular CORDEX-SEA), as well as review and compare additional perspectives from the Southwest Pacific region;
- Collectively assess the progress achieved thus far in order to formulate a set of best practices to advance scientific studies on climate change and its impact in the region;
- Reinforce the sense of a community across Southeast Asia to enhance collaborative and trans-national approaches in tackling climate change challenges. This involves building the foundation for a dedicated climate change effort alongside established initiatives dealing with climate predictions on shorter timescales, with a long-term view to deliver fully integrated climate services.

The workshop structure was designed to meet these various objectives:

- Day 1: a review of the achievements by ASEAN countries in developing national projections;
- Day 2 (AM): a review of the transnational modelling efforts completed across Southeast Asia and the Southwest Pacific region;
- Day 2 (PM): an in-depth review of some of the key scientific questions that need to be addressed in order to have meaningful model-based climate change projections in Southeast Asia;
- Day 3 (AM): a review of the application of the climate change projections by a range of VIA sectors across the region;
- Day 4 (AM): a look towards the future developments in the climate change science globally and in other leading countries of relevance to Southeast Asia, with the intent of informing the discussion on the core objective of developing recommendations for best practices in delivering climate change projections.

In order to achieve the objectives, the workshop gave ample time for discussion, either in breakup groups or plenary sessions:

- At the conclusion of the first two days, the floor was opened to allow free discussion about what was presented during the day;
- From Day 2 onwards, each day started with a summary of the day before to ensure a good all-around understanding of the progress made;
- On Day 3, a full discussion session was dedicated to the challenges of the climate change science and its applications; and
- On Day 4, the Workshop concluded with a second discussion session to develop recommendations toward best practices in generating climate change projections and ensuring their application across Southeast Asia.

2 Workshop Recommendations

2.1 Advancing Climate Change Science Across Southeast Asia

Regional climate downscaling is critical to generating regional specific climate change information across ASEAN countries with complex topography (particularly the Indo-China Peninsula with its numerous mountain chains, coastal plains and river basins) or comprised of thousands of small and large mountainous islands with adjacent seas (such as the Maritime Continent). The climate of Southeast Asia is also complex, ranging from very wet tropical rain forest to the extremely dry areas of northern Sulawesi.

> → *Continued usage and development of regional climate downscaling tools is highly recommended for long-term climate change projection.*

Climate change projections differ between regions in magnitude and sign, warranting high-resolution modelling. Existing studies conducted in the region suggest that temperature will increase everywhere, however depending on emission scenarios, it is expected to increase slightly more across the northern part of the ASEAN region in comparison to the lower latitudes. Changes in mean precipitation are less clear, but in general, there is a tendency for increases in precipitation in the northern regions, and decreases in the southern regions. The precipitation change is also seasonal and location dependent, relating to monsoon signatures across the region.

> → *High-resolution modelling is needed for any specific region both from the scientific perspective and the users' perspective.*

The intensity of large-scale natural climate variability may increase in the warmer climate (e.g. increased impact of ENSO across the Maritime Continent). Projections for the region show that future changes in precipitation across the Maritime Continent may not be spatially coherent and the magnitude of the rainfall variability will likely increase. However, it is also apparent that model sensitivities differ and that may be driving some of the differences in the projected changes.

> → *It is essential to advance the understanding of the physical processes reproduced by regional climate models in order to improve the confidence of the regional climate projections. A useful preliminary step would be to complete a scientific paper reviewing the key physical processes relevant to the region, which can serve as a basis to evaluate models.*

The production of regional climate change projections involves a number of mandatory steps, such as: selection of appropriate GCMs from amongst available global dataset (e.g. CMIP) to provide boundary conditions, integration of a number of regional climate models (RCMs), and bias correction of the RCM outputs for the VIA community. Many methodologies and options currently employed in the creation of national climate projections, while appropriate, may not always be scientifically robust and may depend on external factors (model availability, computing time available, etc.). What is most effective is best determined through a deep and clear understanding of the context and the intended use of the projections. A series of decisions has to be made at each step to optimise this process (e.g. appropriate size of model ensemble, impact of model resolution).

→ *It is recommended to review existing methodologies employed across the region to develop technical guidelines in areas such as downscaling, bias-correction, and the spatial and temporal resolution of the data output in light of the intended usage.*

Climate change projections are scenario-dependent. A clear labelling of emission scenarios is necessary: RCP2.6 is the *best case* aligned with the commitments from the Paris agreement, RCP4.5 is an *optimistic* scenario, and RCP8.5 is a *pessimistic* scenario that also at present the *business as usual* scenario.

→ *It is recommended to continue using multiple scenarios to highlight the benefits of strong mitigation, whilst also acknowledging that more pessimistic scenarios provide stronger (and possibly more likely) climate change signals.*

Very high-resolution models or Convection Permitting Models (CPMs) are recognised as a necessary tool to properly tackle convection, which is the most fundamental rainfall mechanism in the tropical ASEAN region. However, considering their significant computing costs, CPMs come with inherent limits in terms of the range of uncertainties (scenarios, model sensitivity) that can be explored. At this point in time, the added benefit of very-high resolution simulations and the required resolution to properly represent convection is not well-established across the climate of the region.

→ *It is recommended to develop regional technical guidelines on the optimal usage of convection-permitting models to best complement existing climate change information.*

Climate change projections generated from dynamical downscaling (RCMs) methods may be contrasted against projections emanating from statistical downscaling methods (which relies on empirical relationships between large-scale forcing and local scale responses established from observations). Though the motivation for comparison is to increase understanding of the mechanisms at play in a warming world, currently it presents more of an additional challenge than a useful contribution, given a lack of understanding of how to combine information from the two approaches, especially when the projections diverge. However, increasing computing power as well as the recent advances in very-high resolution Convection Permitting Models (CPMs) will provide more opportunities to investigate the reliability of projections from dynamical and statistical downscaling approaches.

→ *It is recommended that appropriate statistical downscaling methods are included in the development of national climate change projections and combined with dynamical approaches to maximise the added value. The optimal integration of these two approaches needs to be addressed in the proposed regional technical guideline.*

Future changes in climate extremes and variability pose significant risks to the region. However, extreme indices commonly used are generic and may not necessarily be well-adapted to the region and the range of users across the VIA community. Developing appropriate extreme indices is a scientific challenge, with users pushing for very high temporal resolution (daily and sub-daily) products. Though these indices can be computed, they may not be scientifically well-grounded.

> → *It is recommended that suitable extreme indices of relevance to the users of climate change information across the region are identified as part of the proposed regional technical guidelines.*

Good observational datasets are required not only in the evaluation of RCMs, but also in the development of appropriate bias-correction methods across the full Southeast Asia domain. Hence, current bias-correction methods are mostly performed for small regions with suitable high density observation networks. Several observational products of different origins are available, such as satellite-based estimates and reanalyses.

> → *It is recommended that a regional study be completed evaluating the persistent differences between various gridded datasets available for the region, as well as outlining the steps for the development of a common dataset to standardize model evaluation.*

Sea level rise poses a major challenge for many ASEAN countries, many of which face increased vulnerability as a result of densely-populated coastlines, mega-cities and low-lying agricultural production regions. It is thus important to put in place robust measures that protect coastal areas and minimise the potential for substantial losses from extreme coastal flooding. The science of sea level rise is complex and evolving rapidly; projections from semi-empirical methods may be much higher than the multi-method synthesised projections from previous IPCC reports, thus opening the possibility for higher upper bounds.

> → *It is recommended that national climate change projections encompass the full envelope of risk associated with global sea level rise, including the low-probability, high-impact plausible scenarios emerging from new assessments conducted overseas.*

2.2 Delivering Climate Change Information Across Southeast Asia

There is now an abundance of climate change information across Southeast Asia; the amount and quality of the products available has grown considerably. This abundance has made it challenging for many ASEAN countries to fully grasp existing data and products, which may in some cases be restricted or difficult to share. Several web-based portals are being developed with a desire to be comprehensive and serve the regional community broadly (e.g. the existing Regional Climate Consortium for Asia and the Pacific (RCCAP) portal, the observation data portal Southeast Asian Climate Assessment & Dataset (SACA&D) and the new CORDEX-SEA related Southeast Asia Regional Climate Change Information System (SARCCIS) portal). All these existing portals are acknowledged as potential solutions, if implemented on a more comprehensive scale.

> → *It is recommended to review the various existing platforms providing climate projection information across Southeast Asia and determine the feasibility of streamlining and/or consolidation.*

A regional consortium for delivering climate projections is a possible approach, as demonstrated by representatives from the Pacific-Australian Climate Change Science Adaptation Planning (PACCSAP) programme from the Southwest Pacific region. This example highlights the need for long-term commitment towards capacity building in order to create a "community of practice." RCCAP, which was developed under the Asian Development Bank (ADB) and piloted by three ASEAN Member States (Indonesia, Thailand and the Philippines), could serve as a framework to adapt the PACCSAP approach to the ASEAN region, but ultimately it was recognized that to be effective, the consortium should be hosted by an organisation with a regional mandate. The Southeast Asian Regional Climate Change Network (SEA-RCC), with its commitment to supporting regional NMHS in delivering climate information and services, is a natural springboard for the proposed consortium. Sources of funding for such development should be sustainable in the long-term. One possible option is for ASEAN to take the lead, possibly by increasing the role of the existing Asian Specialised Meteorological Centre (ASMC). Other sources of funding, such as the Green Climate Fund, the Asia Pacific Network and the Asian Development Bank, were also proposed. It is also recognised that the dissemination of the climate change information is also a key objective of several transboundary organisations dealing with the VIA community (for example RIMES, which guides sectoral agencies in adaptation planning, and AHA Centre, which maintains platforms to aggregate information about climate-related natural disasters).

> → *Support is recommended for the establishment of a Southeast Asian consortium for climate projections and services, aligned with the existing SEA RCC-Network, as well as the Pacific Islands RCC Network. Ideally, the newly-developed consortium will provide a collaborative platform through which authoritative and centralised information may be delivered to the VIA community.*

2.3 Interacting with Users of Climate Change Information

Significant gaps remain between generating climate change projections and using them to make policy decisions. In some instances, there are no climate projections available. In others, projection information may not be useful or appropriate for decision making. There is therefore a need to develop a "science to action" framework in which climate change research is translated into operational resilience and tangible mitigation policies. However, it must also be recognised that many institutions tasked with handling climate data may not be well-equipped to provide climate services and hence it is necessary to build, establish and maintain bridges between the science community and end-users. Early and active end-user engagement to deliver tailored climate services was identified as a key strategy for effective adaptation planning, particularly in fostering a mutual understanding of projection uncertainties. Many Member States have already implemented national platforms for inter-agency dialogue, and due to the varying mandates of the NMHS, a wide spectrum of user engagement and communication strategies exist across the region. However, whilst tailoring climate information to individual stakeholder needs is desirable, it can require considerable time, effort and flexibility that may be beyond the capacity of nationally-mandated bodies. Therefore, there is great value in sharing lessons learnt through stakeholder liaisons.

> → *It is recommended that, as a community expressing willingness to collaborate, we look beyond the exchange of scientific data towards investing in the notion of "sharing of the learning": case studies, interactions between providers and users...*

Many examples emerged during the workshop on the successful uptake of the climate change information during the development of adaptation policies. Some were based on the provision of necessary high resolution information to address microclimatic effects, while others targeted 'worst case' scenarios for risk averse sectors or long timescales required for decision-making (e.g. the expected lifetime of infrastructure). The most effective cases were able to capture the uncertainties associated with projections, building climate resilience through holistic approaches that were adaptive, flexible, and able to prioritise measures to avoid the pitfalls of over-planning.

> → *It is recommended to document successful applications of the climate change science across the region in a scientific paper with multiple authorship.*

Amongst workshop participants, who were predominantly climate scientists, a consensus emerged that the top-down approach to the application of climate change information is limited at best. "Reverse" modelling approaches, which begin with a consideration of proposed adaptation strategies, were identified as innovative co-production strategies to incorporate climate modelling and planning. Engagement of the general public was also identified as important in developing policy to ensure buy-in from the population, with the government playing the leading role in this interaction.

> → *It is recommended that dedicated liaison officers be identified (e.g. climate champions) that could operate with specific sectors but at a supranational level through the right regional mechanism (e.g. ASEAN secretariat).*

2.4 Regional Integration of Climate Change Science and its Application

Climate change is a global phenomenon and its impacts are not defined by political boundaries. Understanding climate variability and change in the Southeast Asia as a whole is critical, relevant, and beneficial for the development of national climate change projections in each country. It is clearly beneficial to aim towards a win-win strategy of close collaboration (and data-sharing) among the ASEAN countries when it comes to the development, improvement and application of the climate change science.

CORDEX-SEA has produced a set of projections, along with scientific analysis and publications, that can be used to support national level climate projections. These projections can also be used to scientifically evaluate methodologies (e.g. bias correction and further downscaling to station-level resolution) in providing information for end-user impact studies. Even in countries where extensive assessments of modelling uncertainties have already been carried out, the CORDEX projections can assess of the robustness of key results. CORDEX-SEA is to be congratulated for the monumental effort in coordinating regional simulations and the achievement of the programme's mission goals. Nevertheless, more can be done to continue to populate the largest possible matrix of GCMs boundary forcings versus RCMs being used in the regions. Furthermore, as CORDEX-SEA embarks on the next challenge of CPM simulations on suitable smaller domains, the very large associated computing cost makes it even more critical that CORDEX-SEA prosper.

> → *It is recommended that all ASEAN countries note the achievements of CORDEX-SEA and prioritise future climate change science to both contribute and benefit from this initiative, in order to 1) maximise the database and available matrix of GCMs vs. RCM simulations, 2) maximise the learning from existing simulations and 3) support CORDEX-SEA in leading the regional community on the path of using CPMs.*

Workshop participants recognised the role that the World Meteorological Organisation (WMO) could play in fostering better collaboration across the ASEAN region with regards to the development of national climate change projections. WMO is the reference organisation for NMHSs and the sponsor of the World Climate Research Program (WCRP), under which the global CORDEX program (including CORDEX-SEA) is being coordinated. In addition, WMO has developed a vision toward the provision of climate services for all timescales, including the longer timescales at which climate change is relevant.

> → *It is recommended that the outcomes and recommendations of this workshop, be presented at the upcoming WMO general assembly for Region V as part of a report on the Working Group for Climate Services (WG-CLS).*

The IPCC will deliver its next Assessment Report (AR6) in 2021. It is anticipated that the community of climate scientists across Southeast Asia can make a strong contribution based on the important work which has been completed since the previous AR5.

> → *It is recommended that Southeast Asia climate scientists aim to have their work published in time to be considered for the next IPCC AR6.*

Coordinating efforts across the community will require leadership and funding support. The question of sustainability and funding for such development was raised, with one possible option for ASEAN to play a greater part, possibly by increasing the role of the existing Asian Specialised Meteorological Centre (ASMC), and another option to explore other funding sources (in particular the Green Climate Fund, the Pacific Network and the Asia Development Bank). The proposal to extend the current scope of ASEANCOF to include climate change projections was also strongly supported. An important component of such development would be to build regional capacity and reduce reliance on external expertise.

> → *It is recommended that the community of climate change scientists in Southeast Asia develop projects endorsed by the ASEAN secretariat and WMO, as well as seek support from relevant financial sources.*

Participants also noted that cross-sectorial platforms such as this “Best Practice Workshop” provide valuable opportunities to foster regional communication on issues of climate change.

> → *It is recommended that a follow-on workshop is organised to review progress on the proposed scientific publications (i.e. regional datasets, weather and climate processes, successful applications of climate change information and guidelines to generate national projections), strategies to embed in existing national projections the new set of global climate stimulations (CMIP6) and strategies to tackle new scientific frontiers, in particular the use of CPMs.*

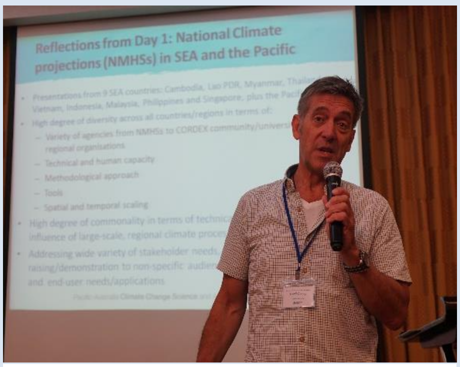
3 Detailed Meeting Report

3.1 Day 1 Presentations: Climate Change Projections from National Meteorological and Hydrological Services (NMHSs)

3.1.1 Summary

Representatives from National Meteorological and Hydrological Services (NMHSs) of 9 ASEAN Member States (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam) presented on the national climate change projection studies and impact management plans developed by each member state. The diversity of methodological approaches to producing downscaled climate projections for policy planning was a reflection of the wide range in technical expertise, capacity and resources, stakeholder needs, organizational structure, and external collaborations/partnerships amongst the Member States. In particular, Member States differed in their (i) use of single- or multi-model ensembles from either CMIP3 or CMIP5; (ii) use of statistically- or dynamically-downscaled models and bias correction; (iii) projections of future means or extremes; and (iv) strategies to utilise climate projections for adaptation planning, including communication of model uncertainties. The participants highlighted the need for standardization, especially in the selection and evaluation of models (GCMs and RCMs alike), which in turn would require improved sharing of observation data and model outputs.

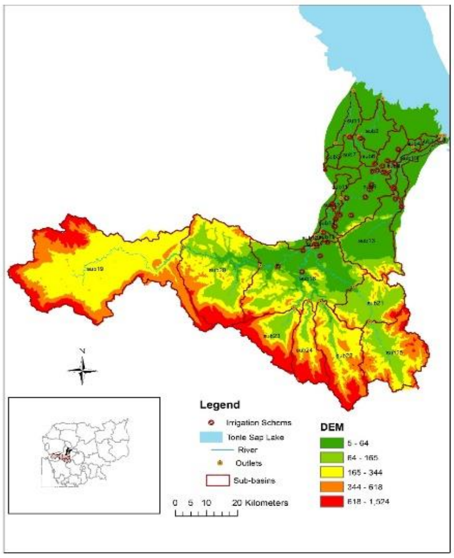
Active end-user engagement to deliver tailored climate services was identified as a key strategy for effective adaptation planning. These “end-to-end” approaches should build upon a mutual understanding of model uncertainties, especially in the representation of natural climate variability and the projection of future extremes. Communication of these uncertainties was identified as a key challenge in delivering climate projections to end-users. Although many Member States have already implemented national platforms for interagency dialogue, there is a great diversity of partnership structures, which may in part be attributed to the varying mandates of the NMHS, resulting in a wide spectrum of user engagement and communication strategies across the region. It was therefore recognised that there is a need to firstly, encourage the building of capacities toward the development of national approaches to climate change science, and secondly to develop regional infrastructure to facilitate coordinated climate change research and knowledge sharing.



Geoff Gooley, CSIRO, Australia, summaries key issues from Day 1 of the Workshop

Representatives from the Pacific-Australian Climate Change Science Adaptation Planning (PACCSAP) programme explained the regional consortium approach to delivering climate projections across the Southwest Pacific region and in particular, highlighted the need for long-term commitment towards capacity building to create a “community of practice.” The Regional Consortium for Asia Pacific (RCCAP), which was developed under the Asian Development Bank (ADB) and piloted by three ASEAN Member States (Indonesia, Thailand and the Philippines), could serve as a framework to adapt the PACCSAP approach to the ASEAN region, but ultimately it was recognized that to be effective, the consortium should be hosted by an organisation with a regional mandate.

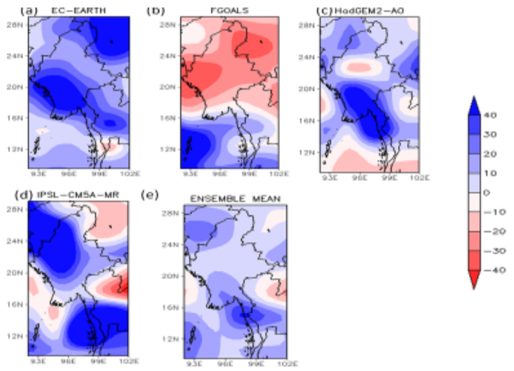
Mr Soim Monichoth, MOWRAM, Cambodia, presented the hydrological modelling of projected changes in water available for irrigation in the Pursat River Basin, Cambodia, using Scenario A1B from the CMIP3 database. The hydrological model (SWAT) was run using statistically downscaled sub-basin scale climate projections derived via SimCLIM climate data analysis tool. Basin flow is predicted to increase under Scenario A1B, with implications for future domestic and commercial water use for irrigation and hydropower. However, in the absence of a full assessment of the uncertainties, it is unknown to what extent these predictions may be dependent on (i) model selection, (ii) emission scenarios and (iii) downscaling methodology. Ms Thelma Cinco, from PAGASA, Philippines, later demonstrated the large difference in projected trends for statistically downscaled versus dynamically downscaled RCM projections for the Philippines, emphasising the need for standardisation and quality control during the evaluation and selection of models for impact studies.



Map of the Pursat River Basin in Cambodia

Mr Sengduangduan Phouthanoxay, MONRE, Lao PDR, explained to the audience Lao's national preparedness and disaster management policies, highlighting the importance of inter-agency coordination via "Ministry Focal Points." It emerged that resource availability and technical expertise remain key challenges for future plans to develop a National Adaptation Plan (NAP) and further national climate change projection research over the period 2013-2020. Lao is faced with challenging meteorological conditions (extreme rainfall during the monsoon season and tropical cyclones) and the priority for the country is to develop a map of risk and vulnerabilities.

Ms Zin Mie Mie Sein, DMH, Myanmar, focused on the future projections of summer monsoon (MJJASO) rainfall over Myanmar under RCP4.5 and RCP8.5 using a sub-selection of CMIP5 models, re-gridded to 50km resolution. 4 GCMs were selected, using a Taylor diagram to compare the suite of 22 CMIP5 model outputs against GPCP historical rainfall (1979 – 2005), although it was noted that the ensemble mean gave the best representation in comparison to any individual model. All selected models project an increase in mean MJJASO rainfall during 2019 – 2045 for all regions in Myanmar, with little variation noted between RCP4.5 and RCP8.5 except in the western region of Myanmar. Ms Sein identified future changes in monsoon rainfall



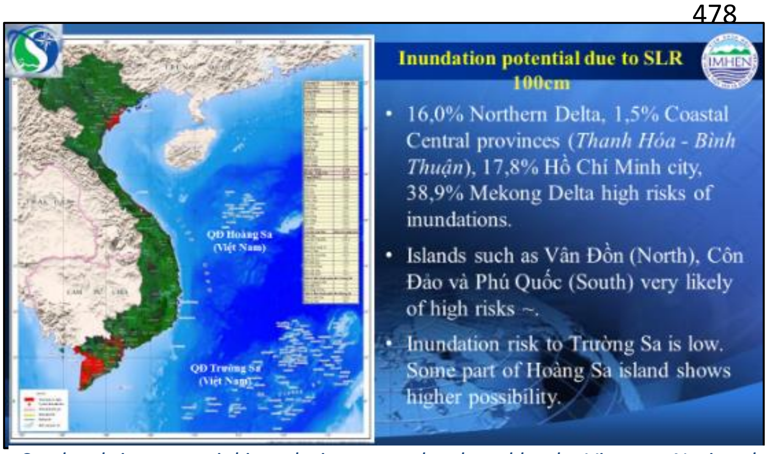
Projected changes in rainfall (%) of MJJASO in 2019-2045 with respect to the reference period 1979-2005 with different GCMs under **RCP8.5**: (a) EC-EARTH (b) FGOALS-g2 (c) HadGEM2-AO (d) IPSL-CM5A-MR and (e) ENSEMBLE MEAN of all four GCMs.

Ensemble member projections of summer monsoon rainfall changes over Myanmar under RCP8.5 from four selected CMIP5 GCMs

variability as a key research focus moving forward, given Myanmar's current vulnerability to flooding from extreme rainfall events.

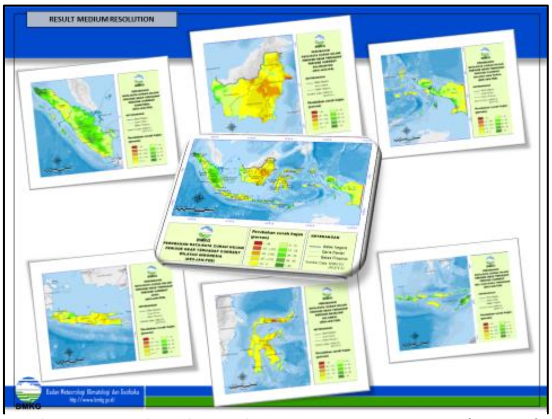
Ms Ruthaikarn Buaphean, TMD, Thailand, presented the projected changes in temperature and rainfall over Thailand under CMIP3-based scenario A2 (ECHAM4) and A1B (HadCM3) using the PRECIS RCM. Although maximum and minimum temperature projections show a clear increasing trend in both scenarios, the projected changes in average rainfall vary spatially across Thailand, with no clear directional trend apart for the rainy season from mid-May to mid-October, where an increase in the north and a decrease in the south suggest a shift of the mean position of the ITCZ across the country. Ms Buaphean also highlighted the mismatch between the model output and historical observation data, and therefore outlined plans to include bias correction in future studies. However, as is also the case for Ms Zin's study, these downscaled climate projections have yet to be incorporated into national impact-based adaptation studies. Ms Buaphean mentioned a collaboration between Thailand and Japan to generate CMIP5-based downscaled climate change projections.

Mr Nguyen Dang Quang, NHMS, Vietnam, presented the national climate change and sea level rise projections for Vietnam, an exercise Vietnam is committed to update every 5 years. The projections presented are comprehensive, being based on dynamical downscaling, using 5 RCMs (AGCM/MRI, PRECIS, CCAM, RegCM, WRF) with bias correction from 16 CMIP5 GCMs under RCP4.5 and RCP8.5 scenarios. Models project an increase in mean temperatures over the whole country, and greater spatial variability for rainfall due to changes in the monsoon regime: i.e. an increase of rainfall between 10 and 20% in the south and a decrease between 5 and 15% in the north. Sea level rise projections were based on the AR5 set of models and used similar analysis from previous studies in Australia, Holland and Singapore to assess the mean sea level rise by 2100 under RCP4.5 and RCP8.5. High-resolution potential inundation risk maps from 1m sea level rise (total sum of projected mean sea level rise and maximum tide) have been developed for deltaic and coastal regions and islands. These maps indicate a potentially very high impact, even without accounting for potential inundation risks from storm surges (e.g. across the Mekong delta up to 40% of the land is at risk of flooding under a 1m sea level rise). Mr Nguyen notes that although workshops have been organised to communicate projection results and uncertainties to different stakeholders, currently the Vietnam Hydrological Meteorological Agency has limited ability to provide specialised climate services to end-users. Mr Nguyen also stressed the need to develop guidelines for bias correction, starting with a systematic analysis of current methodologies in particular to increase the credibility of the projections for users.



Sea level rise potential inundation maps developed by the Vietnam National Hydro-Meteorological Agency. Separate high resolution inundation risk maps for Ho Chi Minh city and Mekong River Delta are also available.

Ms Apriliana Rizqi Fauziyah, BMKG, Indonesia, presented both statically and dynamically downscaled climate projections for Indonesia under RCP4.5 and RCP8.5 scenarios. Statistical downscaling of 6 CMIP5 GCMs (CanESM2, MIROC-ESM, MPI-ESM MR, CNRM-CMS, GDFL-ESM, HADGEM2-ESM) was completed using two methods (an analogue approach and generalised linear model approach) for daily extreme temperature and rainfall and validated against observational (1980 – 2010) and reanalysis data (1971 – 2000). In the meantime, medium-resolution (20km) and high resolution (5km) dynamically downscaled projections were produced with the WRF RCM (driven by the MIROC5 GCM). Plans are in place to deliver these high-resolution climate projection as part of an “atlas of maps” for every major Indonesian island in order to facilitate national adaptation planning. Workshop participants noted the use of the terms “optimistic” and “pessimistic” by BMKG in reference to RCP4.5 and RCP8.5 as an effective method to communicate emission scenarios to end-users. The selection of a single RCM was due in part to previous collaborative linkage, and it was recognised that whilst the project was the first step towards capacity development, future work should look into exploring the performance of a wider ensemble of RCMs.

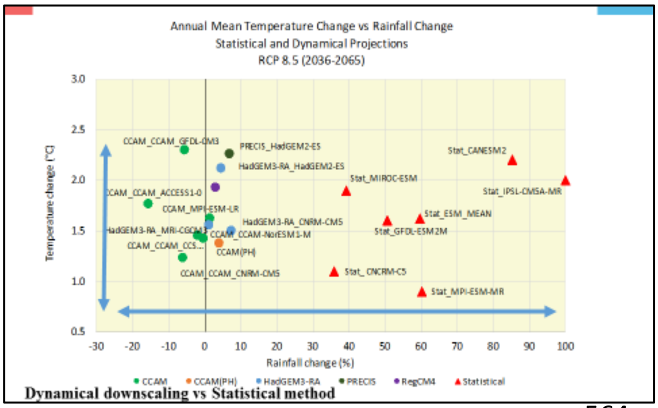


Indonesia archipelago climate projection map (centre) with a selection of medium resolution maps for specific islands as produced by BMKG

Mr Muhammad Firdaus Ammar bin Abdullah, MMD, Malaysia choose a different perspective compared to many presentations and discussed in relation to climate change projections, the operational challenges faced by the Malaysian Meteorological Service (MMD), highlighting the need to improve observational networks to facilitate model validation and understanding of mechanisms driving climate variability. Mr Muhammad stressed the importance of a “science to action” framework, in which climate change research is translated into operational resilience in contrast to a purely academic climate change science aimed at scientific publication. To this end, Mr Abdalah Mokssit, IPCC secretary, called for greater inter-agency dialogue between NMHSs, producers of climate change projections and relevant government stakeholders at a national level first to support international collaboration (i.e. across south-east Asia) second.

Ms Thelma Cinco, PAGASA, Philippines, presented the provision of climate projections for the Philippines using the RCP4.5 and RCP8.5 scenarios. Three RCMs (PRECIS, CCAM and RegCM4) were dynamically downscaled to 25km resolution and the HadGEM3 RCM was downscaled to 12km resolution. The RCMs were driven by 8 GCMs (HadGEM2-ES, ACCESS1.0, CNRM-CM5, CCSM4, GDFL-CM3, MPI-ESM-LR, NorESM1-M, MRI-CGCM3) yielding a 7-model ensemble for RCP4.5 and a 12-model ensemble for RCP8.5. RCM performances were evaluated against observed climatology (APHRODITE gridded dataset) using Taylor diagrams, and showed good clustering for the temperature variable but relatively lower correlation for rainfall. In addition to dynamical downscaling, statistical downscaling was used to project mid-century annual mean temperature change and rainfall change under RCP8.5. The

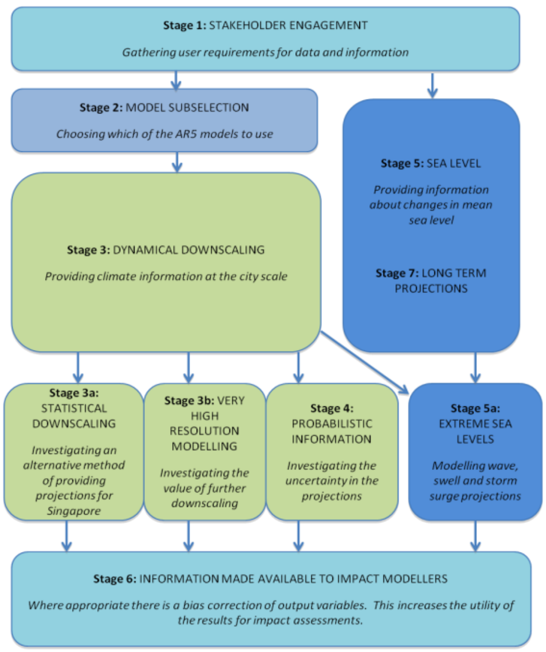

Ms Thelma Cinco presenting Philippines’ PAGASA experience



Comparison of dynamical (circles) and statistical (red triangles) downscaled century projections for temperature and rainfall change for mid-century under RCP8.5 for the Philippines

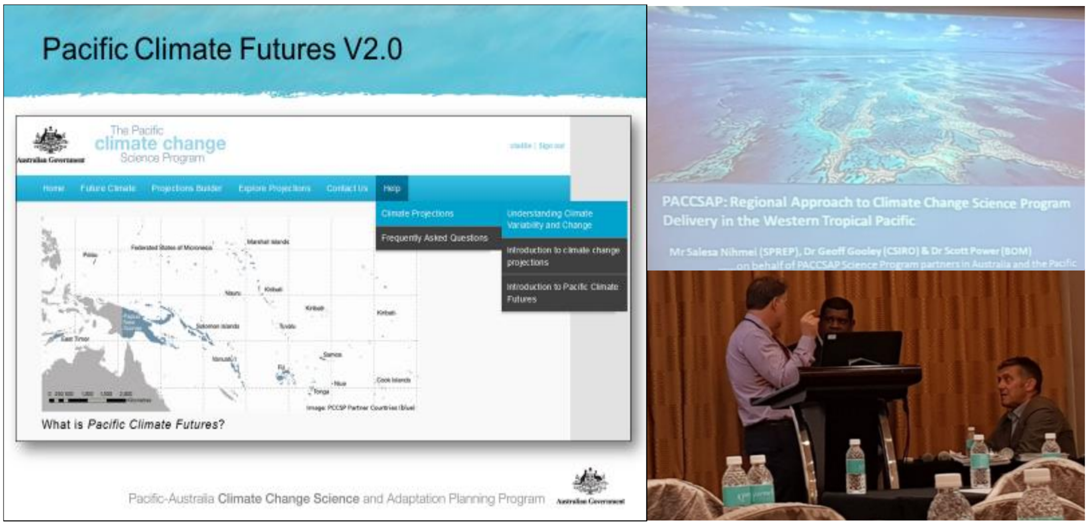
statistically downscaled projections were shown to vary greatly from the relatively clustered RCM ensemble member projections. Ms Cinco postulated that this might be due to the use of absolute humidity at 850 hPa (a quantity which is expected to rise with global warming), in the statistical model. Furthermore, Ms Cinco highlighted the value of comparing model performance not only amongst ensemble members, but also across model generations (CMIP3 vs. CMIP5). PAGASA has published a synthesis report for policy makers on observed historical trends and climate projections for the mid- and end-century. The report outlines ensemble projections of not only mean annual temperature/rainfall change, but also changes in extreme seasonal rainfall (defined as the 90th and 10th percentile rainfall) and tropical cyclone frequency/intensity. To communicate impacts of climate projections to end-users, Ms Cinco demonstrated the use of the Climate Risk Analysis Matrix (CLIRAM), which informs on the risk, potential impact, and adaptation strategies for projected climate changes under each emission scenario, as applied to the agricultural sector in Salcedo. Furthermore, PAGASA is engaged in supporting the Local Climate Change Adaptation Plan (LCCAP) by providing climate projections to local governments. Workshops (e.g. "Training of Trainer") are also conducted to enhance information sharing to end-users. Ms Cinco noted that policy makers require climate projections to be translated into impacts, which often involve estimates of return periods or probabilities. It is therefore crucial that model uncertainties are effectively communicated to end-users.

Mr Chris Gordon, Senior Advisor of CCRS, Singapore, presented the 2nd National Climate Change Study for Singapore, conducted jointly by the Centre for Climate Research Singapore (CCRS) and the UK Meteorological Office (UKMO) Hadley Centre. Mr Gordon emphasised end-to-end stakeholder engagement as a contributor to the successful integration of the study results into national impact assessment and adaptation strategies, implemented under the inter-agency Resilience Working Group (RWG). Preliminary engagement allowed scientists to anticipate projection requirements of downstream impact modellers and suggest alternatives when requirements could not be supported on a sound scientific basis. Dynamically downscaled projections for RCP4.5 and RCP8.5 were generated using the PRECIS RCM at 12km resolution driven by a sub-selection of 9 CMIP5 GCMs. Bias correction was applied to the end products and found to be essential for impact



Overview of the various stages involved in the completion of Singapore's 2nd National Climate Study modelling, though this was only done for the Singapore output as a similar work across the full domain would be difficult due to uncertainties in the observations. Multiple model sub-selection criteria were used to judge the skill of the GCMs, including representation of monsoon flow, Pacific Ocean and El Nino Southern Oscillation (ENSO) teleconnections. Models were also strategically chosen to span the range of climate sensitivities. Downscaled simulations were shown to improve representation of the annual precipitation cycle over equatorial Southeast Asia compared to the host GCM. The study was documented by a synthesised report of ensemble climate projections, aimed at stakeholders and policy makers, as well as a series of technical reports focusing on various aspects of the generation of the results. Mr Gordon identified the modelling of extreme rainfall, treatment of the urban landscape, representation of natural decadal climate variability (and its interpretation by stakeholders) and understanding of the contribution to sea level rise by various components as key challenges for Singapore moving forward. He also pointed that the synthesis of model projections was critical in more effectively communicating uncertainties associated with climate projections.

Mr Geoff Gooley, CSIRO, Australia, **Mr Scott Power**, BoM, Australia and **Mr Salesa Nihmei**, SPREP, Samoa, presented on the experience of the Pacific-Australian Climate Change Science Adaptation Planning (PACCSAP) programme in delivering climate projections to the Western Tropical Pacific Ocean, an ambitious task considering the region is 10 times the size of Europe and made of small islands of comparable size to Singapore. Given the isolation of Pacific Island Member States and their diversity of technical capacities, it was recognised that a regional



PACCSAP Climate Futures Portal delivers climate change projection information across the Southwest Pacific

approach was necessary to effectively produce and communicate climate projections to the public. Regional coordination was facilitated through SPREP, a 25-year old institution and the leading inter-governmental organization on climate change and environmental monitoring in the Pacific region. The science component of the PACCSAP programme was committed to improving understanding of climate change science in the region. In addition to conducting research into climate projections, a number of data analysis tools were created to enhance technical support and the dissemination of information. These include the Pacific Climate Futures V2.0 portal, which gives users access to downscaled CMIP5 data, and the Climate Data for the Environment (CLiDE), a tool now used operationally for data storage and management. Some creative initiatives to educate the public on key climate components, such as ENSO, were developed (e.g. the "*Climate Crabs*" animation video). These videos, which are available online and have been translated in 6 local languages, helped raise awareness across all levels on climate change, and were complementary to the numerous training workshops and collaborations organised for capacity development in the region. In order to enhance sectorial engagement, PACSAPP generated tailored climate projection reports for each participating Pacific Island country. The Regional Summary of New Science and Management Tools, a comprehensive report on the methodology of generating projections specifically targeted at non-technical stakeholders, as well as Fact Sheets on key climate issues, were also identified as successful information sharing initiatives. Mr Salesa noted that although the PACCSAP programme has concluded, it is crucial to sustain links and partnerships developed through the programme.

In adapting the PACCSAP model to the ASEAN region, the RCCAP pilot study was identified as a possible starting point. At present, RCCAP is in its infancy for the ASEAN community since only 3 Member States (Indonesia, Philippines, and Thailand) are included. Nevertheless, it presents a real opportunity going forward as this tool could easily be developed further for the full ASEAN community, provided a "*champion*" could be identified within the region to lead the initiative.

Mr Gooley noted that if this tool were to be adopted by the full ASEAN community, it would form a natural bridge between the Southwest Pacific and Southeast Asia communities as the portal development will continue under Australia leadership (CSIRO and BoM) for the Southwest Pacific region.

Workshop participants exchanging experiences during the break on the first day of the workshop

3.2 Day 2 Presentations: Scientific Achievements and Challenges in Delivering Regional Climate Projections

3.2.1 Summary

International experts from UKMO, CSIRO, and BoM, along with regional experts from the CORDEX-SEA community, and from Singapore institutions (CCRS, TMSI, EOS) provided an overview of the key challenges in delivering downscaled regional climate projections for the ASEAN region. Climate projections are now available from a variety of RCM simulations performed by NMHSs in collaboration with international organisations (such as the UKMO and CSIRO) and also through regional collaborative initiatives such as CORDEX-SEA. Both have encouraged local capacity building across many member states. This now presents a new challenge on how best to coordinate, combine and synthesise data from multiple sources and methodologies, and deliver consistent climate information to national stakeholders.

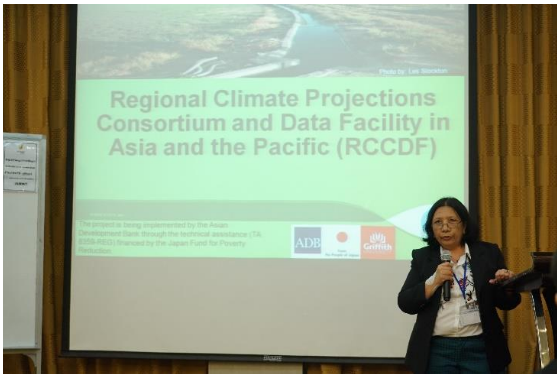
Southeast Asia is a region with high climate risk, but low adaptive capacity. Infrastructural vulnerability to extreme events (such as floods and droughts, tropical cyclones and typhoons) is often the immediate priority for policy makers. There is a need to first adapt to naturally occurring climate variability before attempting to assess and defend against changes in climate risks from anthropogenic climate change. Hence, understanding how drivers of natural climate variability, such as the El Nino Southern Oscillation (ENSO), will respond to future climate change remains a key area of research interest. Besides changes in climate variability, reliable estimates of long-term mean climate changes, such as sea level rise, are integral for the sustainable development of the region. Very high-resolution convection-permitting simulations are also starting to show real success in improving model representation of extreme rainfall. These high-resolution models have also been used to estimate future risks from extreme sea level change due to storm surges.

Participants called for the development of standardised procedures for model selection and intercomparison, regional process studies, assessment of natural variability, the treatment of model biases and errors, and RCM domain selection criteria. Discussions drew upon examples of good practices exhibited by a number of ASEAN NMHSs in their production of national climate projections and also highlighted the need for enhanced data sharing within the region. Such development would improve the understanding of the uncertainties surrounding national climate projections, which are always incomplete. In addition, active stakeholder engagement during the production of climate projections could aid in educating users on the uncertainties associated with climate projections. However, it was recognised that this requires strong and sustained collaborative links, considerable time, effort, and flexibility that may be beyond the capacity of nationally mandated bodies. Therefore, there is great value in sharing lessons learnt through stakeholder liaison across Member States.

However, given the absence of a strong regional platform for collaboration on climate change projection research, substantial cross-institutional collaboration of this nature remains currently immature. On the issue of data collection, storage and sharing, portals such as the SEA Regional Climate Change Information System (SARCCIS), the Southeast Asian Climate Assessment Dataset (SACA&D) and the Regional Consortium for the Asia Pacific (RCCAP) were acknowledged as potential solutions, if implemented on a more comprehensive scale. Moving forward, participants called for a regional framework for communication and collaboration between Member States, in hopes of consolidating the diversity of research currently being conducted across the region.

Mr Geoff Gooley and Mr Marcus Thatcher, CSIRO, Australia, demonstrated the Pacific Climate Futures web-based climate impacts decision-support tool developed by the Pacific Climate Change Science Programme (PCCSP) and the PACCSAP Science Programme. Climate Futures includes projections from CMIP5 and CMIP3 GCMs, as well as a selection of downscaled projections from the CCAM RCM. The portal is designed to provide information about the range of climate change projections and guidance in navigating the uncertainty space surrounding the projections for their use in impact assessment. Information is presented in three levels of increasing complexity to cater to users with a diversity of technical expertise.

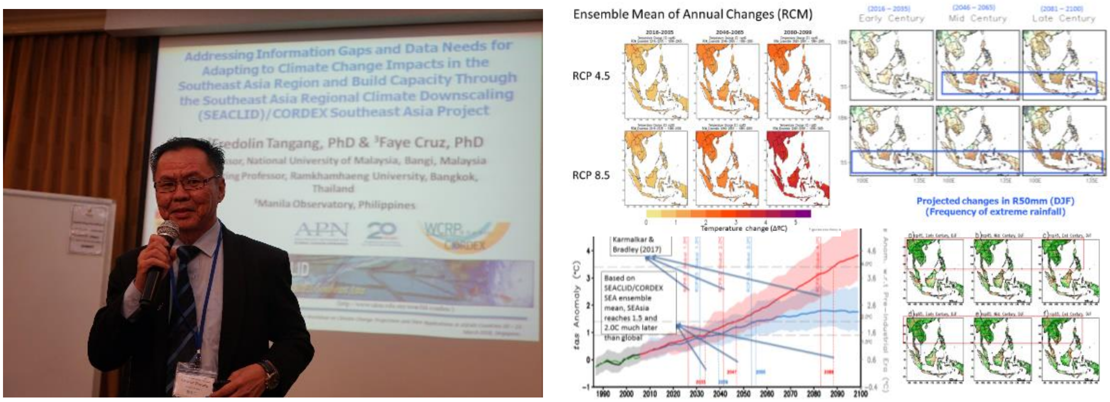
Ms Rosalina De Guzman and Ms Thelma Cinco, PAGASA, Philippines, demonstrated theRCCAP portal established by the Asian Development Bank (ADB) to provide climate change information and guidance material for adaptation planning in the region. The portal also provides detailed case studies on the use of climate projections for impact assessment in various regional sectors. Guidance material of this nature was acknowledged as particularly effective in educating end-users and decision makers on the appropriate use of climate projection information.



Rosalina De Guzman giving an overview of the RCCAP climate change information portal

Mr Fredolin Tangang, UKM, Malaysia, and main coordinator of CORDEX-SEA, described the achievements of the first phase of CORDEX-SEA regional climate downscaling programme, a collaborative initiative started in 2013, which involves 14 countries and now includes 7 ASEAN Member States (5 performing simulations) in order to build local capacity and expertise. Mr Tangang identified the relative lack of climate change impact assessment studies in the Southeast Asian region in the IPCC AR5 report as a motivating factor to establish CORDEX-SEA as well as the high number of climate vulnerabilities (floods, cyclones, trans-boundary haze episodes). Ensemble members were comprised of seven GCMs (CNRM-CM5, CSIRO-Mk3-6-0, EC-Earth, MPI-ESM-MR, CNRM-CM5, HadGEM2-ES, HadGEM2-AO) that were downscaled to 25km using primarily three RCMs (RegCM4, RCA4, WRF), although the full matrix of each combination of GCM and RCM had not been completed. Selected GCMs had to have complete RCP4.5 and RCP8.5 scenarios, with further elimination of models based on unrealistic simulations of current climate, particularly in the representation of monsoon circulation and seasonal/annual rainfall distribution. In addition, when downscaling of a particular GCM led to significant climate drift, the downscaling simulation was also discarded. The consistency of projected annual and seasonal changes between the multi-model RCM ensemble and the GCMs was also assessed. The RCMs were found to reduce biases observed along island boundaries, likely induced from poor representation of the topography in the GCMs. This provides compelling evidence of the added value in using RCMs and the continuing push for higher resolutions. Mr Tangang outlined plans to further downscale to 5km for five regional sub-domains within CORDEX-SEA full domain during the next phase of the programme. Furthermore, high-resolution projections will also be invaluable for adaptation planning, as policy makers often require robust information on the local scale, for example within administrative boundaries, agricultural sectors, or river catchment basins. Projections of regional extremes, represented by the CDD, R50mm, and RX1day climate indices, were also generated to contribute to national impact assessments. Scientific findings from the CORDEX-

SEA programme have been published in a number of eminent research journals, and there are plans to produce a Policy Report as well. Mr Tangang also highlighted the proposed active involvement of CORDEX-SEA in the upcoming IPCC AR6 report.



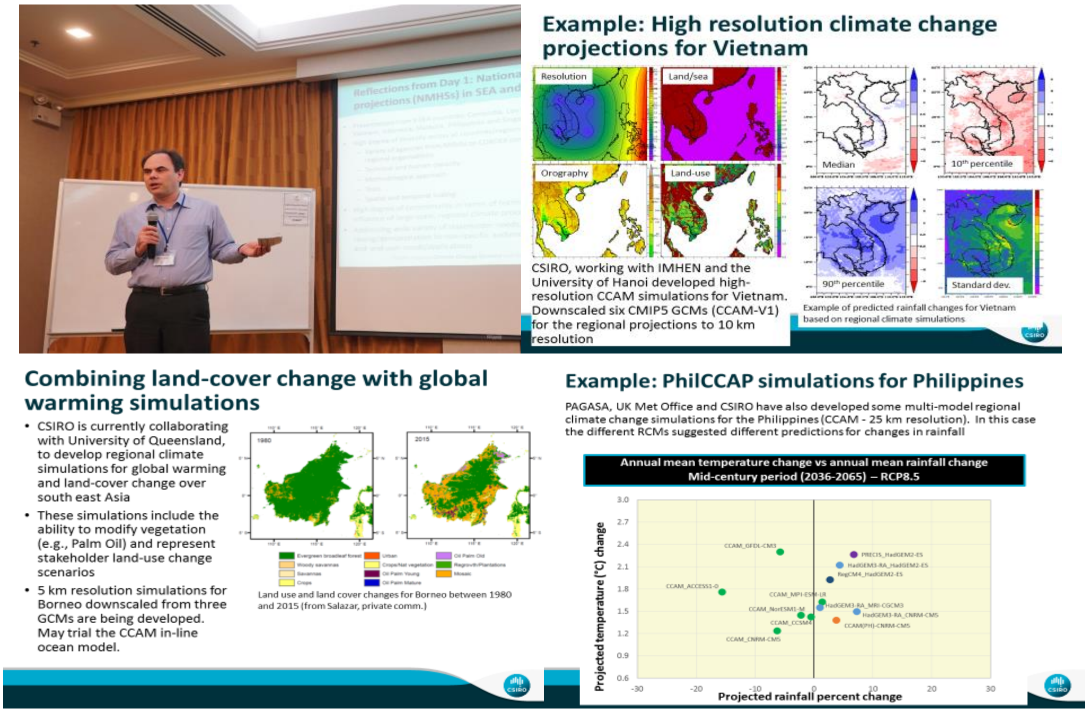
Fredolin Tangang summarising the achievements of CORDEX-SEA in delivering downscaled climate projections for the region

The Southeast Asia Regional Climate Change Information System (SARCCIS), an online portal for free data dissemination managed by the Ramkhamhaeng University Centre of Regional Climate Change and Renewable Energy (RU-CORE), Thailand, in collaboration with the National University of Malaysia, is to be launched in May 2018. Training workshops will be conducted to educate users on the use, analysis, and interpretation of climate data from the portal, therefore reaffirming CORDEX-SEA’s commitment to enhancing knowledge on regional climate change in the region. SARCCIS complements existing capacity building initiatives, such as the Modelling Training Workshops organised in collaboration with ICTP Italy and NCAR. Workshop participants congratulated Mr Tangang on the monumental effort involved in the coordination of CORDEX-SEA and the achievement of the programme’s mission goals, and further stated the need to exchange lessons learnt from the CORDEX-SEA downscaling experiment, and other regional CORDEX initiatives, for the benefit of the region.

Ms Nicola Golding, UKMO, United Kingdom, discussed the challenges for the region in the provision of climate projections for adaptation planning. Ms Golding highlighted issues of model biases and errors, domain choice, sampling uncertainties, model resolution, and utility of projection information as key challenges for the region. Significant errors remain in the simulation of clouds and associated cloud feedbacks, though the latest CMIP5 models have improved in their representation of observed climatology, particularly as a result of improved physics and model resolution. However, consistency of ensemble member projections should not be the primary goal during model selection. Ms Golding highlighted the selection criteria during the 2nd National Climate Change Study in Singapore, which included “biased/significantly biased” models as outliers in order to span a representative range of projections. She mentioned very high-resolution convection-resolving models as a possibility to remove systematic model biases in the representation extreme rainfall. However, computing costs currently inhibit high-resolution downscaling over extensive spatial domains, limiting their potential application across the ASEAN region. With regards to the diversity of downscaling methodologies across the region, there needs to be a discussion on how to compare and combine the often contrasting projections from the different models. A recurring theme during the Workshop was how to synthesise highly technical climate change information for local and national decision-makers. Ms Golding identified the CLIRAM system developed by PAGASA as a particularly effective communication tool. Climate projections could also be directly tailored to guide adaptation strategies. The "reverse" modelling conducted under Climate Science for Service Partnership (CSSP) in Shanghai, which began with a consideration of proposed adaptation strategies, was praised as an innovative co-production strategy to integrate climate modelling and urban planning. However, applied modelling of this nature requires considerable cross-sectorial knowledge exchange, and is further limited by the lack of bridging expertise in the region; Ms Golding introduced the notion of "sharing of the learning" as we progress in our practices as a community in SEA.

CLIRAM information representation system developed by PAGASA and the UKMO to synthesise climate projection data for local policy makers

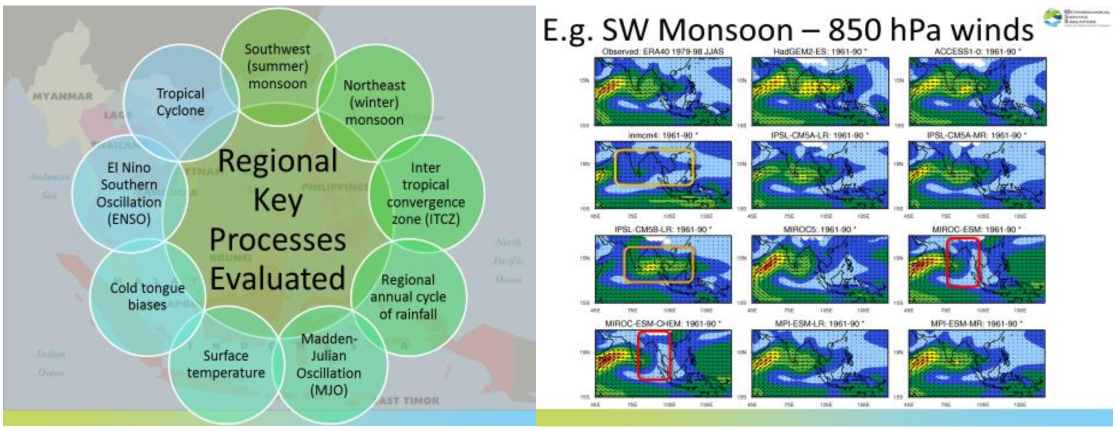
Mr Marcus Thatcher, CSIRO, Australia, presented CSIRO's contributions to the production of dynamically downscaled climate projections in Southeast Asia and the Pacific. Mr Thatcher outlined CSIRO's collaborations in the region with Indonesia, Malaysia, Philippines, Thailand, and Vietnam, as well as its involvement in the development of RCCAP and CORDEX-SEA.



Marcus Thatcher presenting CSIRO's contributions to delivering climate projections to Southeast Asia.

Downscaling was performed using the Conformal Cubic Atmospheric Model (CCAM), a variable-resolution (stretched-grid) global model. Monthly sea surface temperature (SST) biases were first corrected before downscaling via CCAM to 50km to perform CORDEX simulations. Further downscaling at 10 and then 2km resolution was also undertaken for national projections. Mr Thatcher indicated that in addition to data availability and model representation of present climate, parent GCMs were also selected to represent a broad range of possible futures. CSIRO has collaborated with IMHEN and the University of Hanoi to downscale 6 CMIP5 GCMs to 10km resolution to provide regional climate change projections for Vietnam. Under PhilCCAP, CSIRO has also collaborated with the UKMO and PAGASA to deliver 25km multi-model regional climate change simulations for the Philippines. Currently, CSIRO is collaborating with the University of Queensland to develop very high-resolution regional climate simulations to investigate the impact of land-cover change over Southeast Asia.

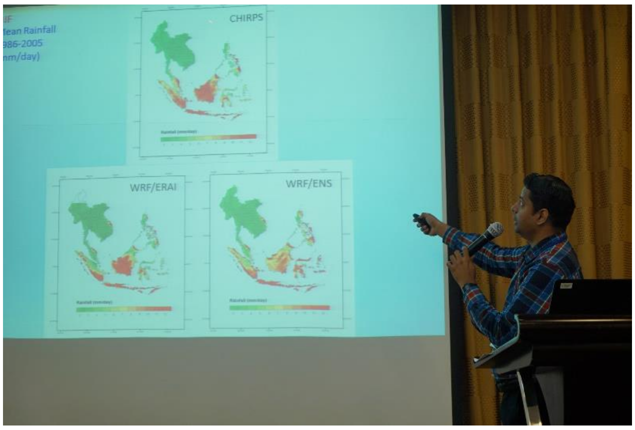
Mr Muhammad Eeqmal Hassim, CCRS, Singapore, presented the regional climate modelling over Southeast Asia performed under Singapore's 2nd National Climate Change Study. Nine CMIP5 GCMs were strategically sub-selected to (i) include the most skilful models; (ii) span the plausible range of projections; and (iii) ensure the most efficient use of resources. Mr Hassim outlined the decision making matrix used to evaluate GCM during the selection process, which systematically sampled GCMs based on model performance and representative position in the projection range. Models' performances were judged on the representation of key regional climatological processes: Southwest (summer) Monsoon, Northwest (winter) Monsoon, Intertropical Convergence Zone (ITCZ), regional annual cycle of rainfall, Madden Julian Oscillation, surface temperature, cold tongue biases, ENSO and tropical cyclones.



(Left) Key processes studied to evaluate model performance during the GCM selection process. As an example, climatological winds (right) were used to evaluate model representation of the Southwest monsoon.

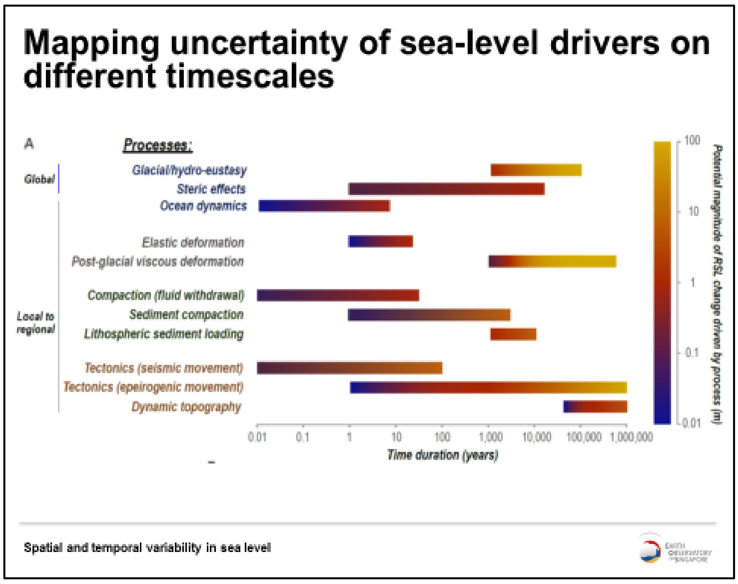
The nine selected GCMs were downscaled using RCP4.5 and RCP8.5 scenarios (from 2006 to 2100) to 12km using PRECIS V2 with historical simulations (from 1959 to 2005) also completed for model evaluation purposes. Regional-scale evaluations of historical simulations were performed to ensure consistency between GCMs and RCMs, and to check for accurate representation of regional climatology and ENSO teleconnections. Mr Hassim presented the projection results for RCP8.5 from the study, noting the enhanced warming signal over land, the drying signal over the southern region of Southeast Asia during the Southwest Monsoon, and the wet signal over much of the region during the Northwest Monsoon. Projected changes in rainfall are larger than natural inter-decadal variability over much of the model domain. However, at 12km resolution, the RCM struggles to represent Singapore's seasonal and diurnal rainfall cycle as well as rainfall extremes over Singapore. Therefore, bias-correction by quantile matching was performed for climate change projections over Singapore. Participants suggested that the robustness of regional projections could be evaluated by comparing against other simulations performed in the region using different model domains (e.g. CORDEX-SEA simulations). It was also acknowledged that RCP2.6 should be considered to demonstrate the benefits of very strong climate change mitigation in light of the subsequent Paris Agreement.

Mr Srivatsan Raghavan, TMSI, Singapore, presented the dynamical downscaling over Southeast Asia performed by the Tropical Marine Science Institute (TMSI) of the National University of Singapore (NUS). Downscaling to 20km resolution was performed using the WRF model, driven first by ERA-Interim reanalysis for model evaluation purpose, and then a selection of 5 GCMs (ACCESS1.0, MPI-ESM, MIROC5, HadGEM-AO, CCSM4) under RCP4.5 and RCP8.5. Model representation of regional rainfall climatology was evaluated against the CHIRPS gridded dataset, which was shown to perform better than APHRODITE over the Maritime Continent region. However, at 20km resolution the model is unable to accurately represent the annual rainfall cycle over Singapore, unlike other major cities in Southeast Asia. Mr Srivatsan presented the projection results from the study, highlighting the general drying pattern over southern Southeast Asia during JJA (an important result for future transboundary haze episodes), and the widespread warming signal over much of the region. Higher resolution simulations (at either 10 or 5km) are underway, possibly as a contribution to the second phase of CORDEX-SEA. As part of his presentation, Mr Srivatsan stressed the need for a common dataset for the region to standardize model evaluation, later demonstrating the persistent differences between various gridded datasets available for the region.



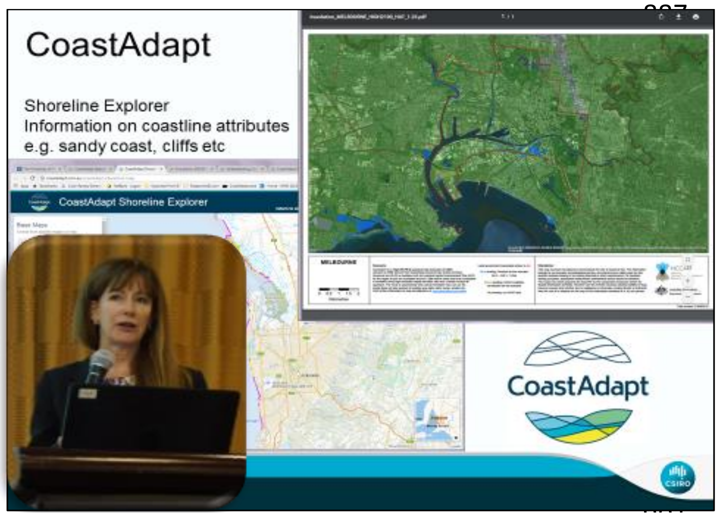
Srivatsan Raghavan presenting on the dynamical downscaling projects conducted by TMSI, highlighting the differences in regional climatology as represented by the various available datasets

Mr Benjamin Horton, EOS, Singapore, discussed the use of records of past and present sea level change to constrain future sea level projections. As sea level rise is driven by a number of processes operating on a variety of temporal and spatial scales, it is necessary to understand the main sources of uncertainty operating at each scale of interest. Although global drivers, such as thermosteric effects, ocean dynamics, and glacial isostatic adjustment, are well constrained, significant uncertainty remains on local scales due to the scarcity of observational datasets to constrain rates of local tectonic processes. An understanding of past relative sea level change can inform on potential rates of future sea level rise. Mr Horton outlined the steps required to reconstruct past sea level change using palaeoenvironmental indicators of past tidal zones, which are geological proxies of relative sea level. However, records of Holocene sea level change are largely concentrated in the northern high latitudes (in formerly glaciated regions now undergoing glacial isostatic adjustment), with only a few records available for the Southeast Asian region. More recent sea level change over the 20th century can be constrained to much higher precision using instrumental tide gauges, although once again data coverage is unevenly distributed, with significant gaps for the Southeast Asia region. Mr Horton outlined a potential solution using annually banded coral microatolls as proxy tide gauges. Projections of future sea level change also clearly highlight the value of mitigation. Mr Horton stressed that projected rates of sea level rise under RCP8.5 may be indefensible for both urban infrastructure and natural environments (e.g. 30 mm/year rates are faster than what natural environment can adapt to, which ranges from about 10 mm/year for mangroves and 200 mm/year for coral reefs). Mr Horton also demonstrated that projections from semi-empirical methods may be much higher than the multi-method synthesised projections from the IPCC reports, though this may be a result of differing methodologies to quantify upper bounds. An important discussion followed his presentation on how IPCC reports have captured the upper end of the range of future sea level projections over time and if this is accurate.



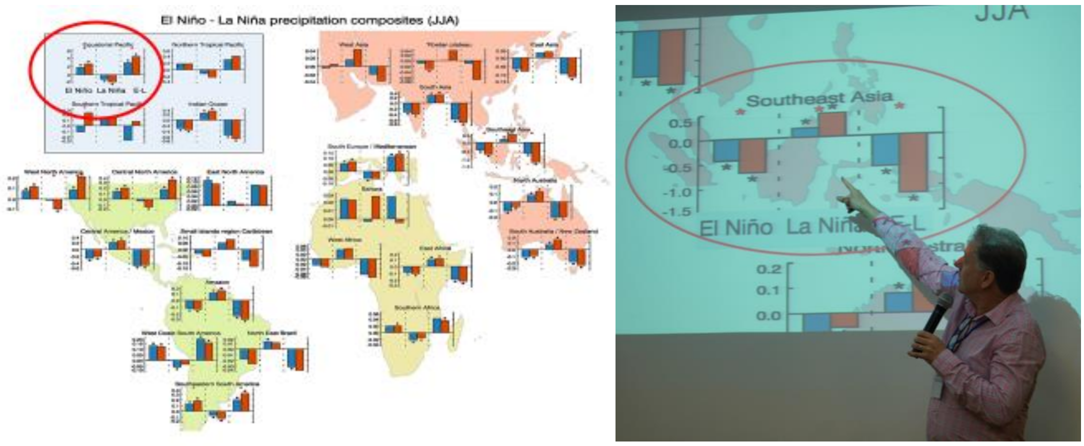
Characteristic timescales and potential magnitudes of various drivers of relative sea level change

Ms Kathy McInnes, CSIRO, Australia, presented CSIRO's contribution to delivering sea level projections for the Pacific and Southeast Asian regions. Sea level in the region responds strongly to seasonal cycles (e.g. monsoon fluxes) and modes of naturally occurring interannual variability (e.g. ENSO, IPO, PDO). By separating these influences from projections, for example via multiple linear regression, the anthropogenic contribution to future sea level rise can be determined. Ms McInnes demonstrated that when natural variability is removed from tide gauge data from Malaysia, this gives a reduced estimate of historic sea level rise trends that is more in line with the global average over the same time period. There is also a need for more comprehensive modelling of sea level drivers, including ice sheet dynamics and local tectonic movements. In Australia, sea level projections are delivered via online visualisation tools such as Marine Explorer and CoastAdapt, which provide users information on potential inundation risks under different emission scenarios, as well as adaptation plans to cope with sea level rise. Ms McInnes also mentioned the impact of extreme sea level rise from storm surges, which have had a particularly devastating impact on some Pacific island nations due to their unique coastal bathymetry. However, tide gauges do not capture extreme wave swell events as these instruments are placed in sheltered marine locations where wave energy is



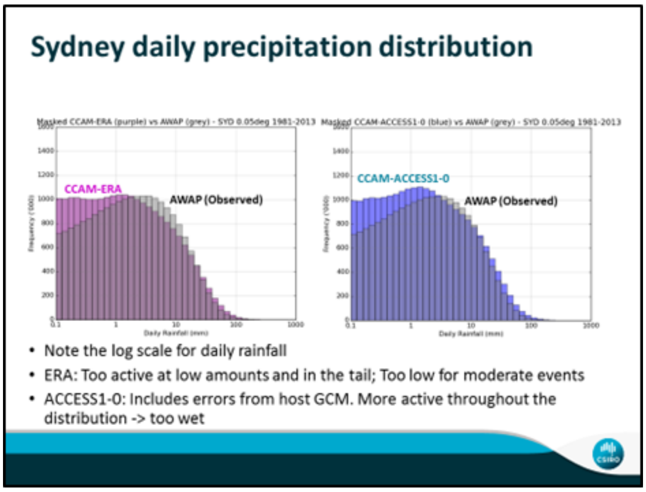
The "CoastAdapt" portal to deliver sea level rise projections for individual coastal councils in Australia dampened. Hence, data on sea level extremes is limited and tide gauge data cannot be used to reliably estimate storm surge return periods. Under the PACCSAP programme, stochastic modelling of synthetic cyclones was used to estimate storm tide return periods for Apia, Samoa.

Mr Scott Power, BoM, Australia, discussed future projections of ENSO and its global impacts over the next century. ENSO-driven rainfall variability in the Pacific is projected to increase, with robust signals across both CMIP3 and CMIP5 models and all scenarios, despite uncertain signals of projected changes in ENSO-driven SST variability. This will likely lead to increases in the frequency of major disruptions of rainfall patterns in the Pacific. In fact, the risk of major disruption may already be inflated at present, and is projected to increase further - even under RCP2.6. Similar increases in ENSO-driven variability can be observed in a majority of regions around the world, though in Southeast Asia rainfall variability during El Niño (La Niña) years will be offset (intensified) somewhat by the general increase in mean annual rainfall as a result of global warming. However, although CMIP5 models tend to agree on the sign of ENSO teleconnections around the world, Mr Power noted that models still have difficulty in simulating certain aspects of the Pacific climate, such as long-term average sea-surface temperature (SST) patterns, the temporal behaviour of ENSO, and multi-decadal changes in both SST and the Pacific trade winds. This lowers confidence in conclusions about the impact of global warming on ENSO.



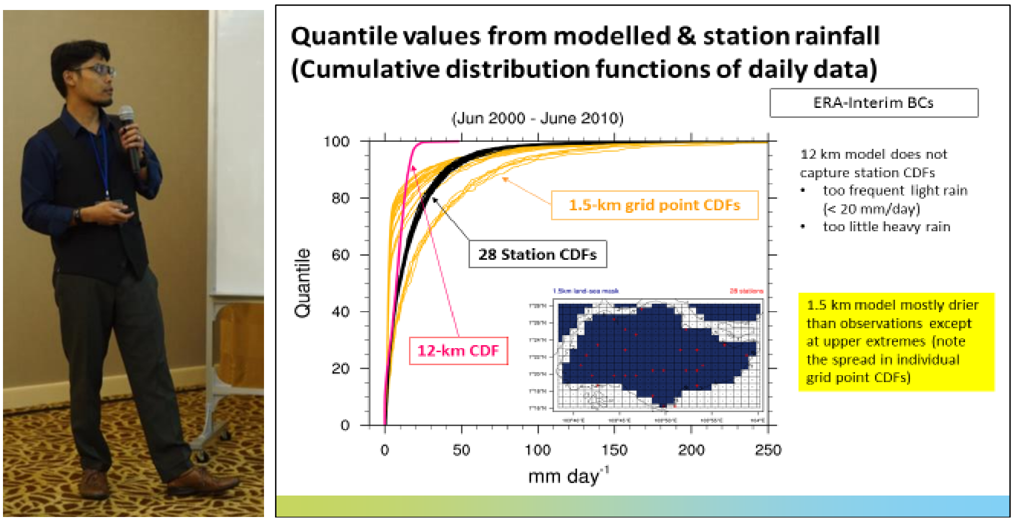
Scott Power highlighted the projected changes in ENSO variability for the region

Mr Marcus Thatcher, CSIRO, Australia, presented CSIRO's experience with convection-permitting modelling using CCAM. Mr Thatcher outlined three high-resolution climate simulations for Australia. Firstly, an extreme rainfall study for Sydney was conducted by downscaling ERA-I reanalyses (1980 – 2013) and ACCESS1.0 (1981 – 2015 and 2040 – 2065 for RCP8.5) to a convection-enabling resolution of 2km resolution (nested within the 50km global CCAM model). Model results were evaluated against the 0.05° AWAP gridded dataset from the Australian Bureau of Meteorology. Significant improvement in model representation of orographic topography in the Sydney region was noted. Downscaled simulations of the observed climate were able to capture the observed probability distribution of daily rainfall, though with some errors. The CCAM-ERA model was shown to be overactive for low rainfall events and underactive for moderate rainfall events, while the CCAM-ACCESS model was shown to have a slight wet bias throughout. Under RCP8.5, the CCAM-ACCESS model projected a shift in the rainfall probability distribution from moderate events to lower and heavier events, consistent with decreasing average rainfall but increasing extreme rainfall. Considerable spatial variability in the distribution of extreme rainfall (represented by the 95th percentile rainfall) was observed, with locally averaged changes of between -5 to +20%. Secondly, convection-enabling simulations were performed at 5km resolution for Victoria. Downscaled projections of 3 GCMs (NorESM-1, CNRM-CM5, HadGEM2-CC) under RCP8.5 indicated enhanced drying over elevated orography in Victoria by the end of the century. Finally, convection-permitting simulations have been used to explore urban climate modelling under the urban canopy scheme (UCLEM). These simulations will be used to explore the impact of green spaces and urban building materials, and can be combined with regional air quality simulations to investigate health impacts. Future work into the modelling of cyclones, hail, and fire weather is currently being conducted under the National Environmental Science Programme (NESP). Workshop participants noted that parameterisation of shallow convection is still necessary at resolutions coarser than 1km. Considering the significant computing expense required to run very high-resolution models, and therefore the inherent limits to improving resolutions, participants called for recommendations on the best resolution to run convection-permitting models without significantly compromising model output.



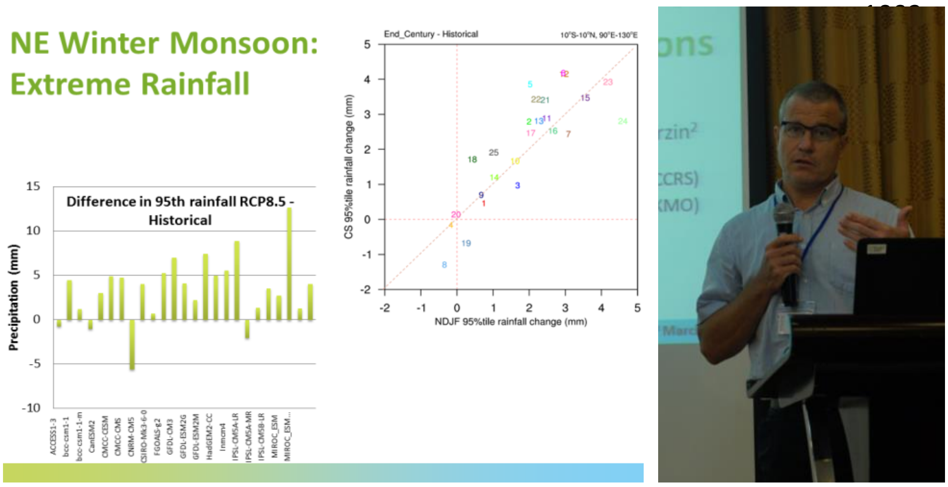
Comparison of downscaled model daily rainfall distribution against observed AWAP dataset

Mr Muhammad Eeqmal Hassim, CCRS, Singapore, showcased Singapore's experience performing convection-permitting simulations of the regional climate using the Unified Model (UM) in its PRECIS V2 version at 1.5km resolution via multiple-model nesting within parent model domains, from 12km to 4.5km and to 1.5km resolution. Historical runs were driven by ERA-I reanalysis and end-of-the-century projections under RCP8.5 were driven by HadGEM2-ES reanalysis. The 1.5km model resolution allowed for explicit mid- and deep-level convection, with parameterized shallow convection. At 12km resolution, downscaled RCMs are still unable to resolve Sumatra squall events and local convective rainfall, which are key drivers of extreme rainfall in Singapore. However, the very high-resolution simulations (1.5km and 4.5km) displayed more realistic storm structures and propagation, rain rates, timing of diurnal rainfall cycles, and annual rainfall cycles. In particular, the very high resolution models did not produce the unrealistic land-sea rainfall contrast typical of the 12km model. However, the 1.5km model was mostly drier than observations, except at the upper extremes, with a persistent dry bias observed over the sea in all seasons. Mean and extreme rainfall during JJA were also found to be poorly represented in the 1.5km model, and may be related to the sensitivity of explicit convection to steep topography. Nonetheless, there are significant improvements in the representation of the cumulative rainfall distribution pattern in the 1.5km model (for both ERA-I and HadGEM2-ES) as compared to the 12km RCM. Mr Hassim noted that the difference between the 12km model and the 1.5km model is dominated by the difference between the 12km model and the intermediate nested 4.5km model, suggesting the model improvements are largely due to the change from parameterised to explicit representation of mid- and deep-level convection.



Muhammad Eeqmal Hassim presented on the comparison of Singapore rainfall cumulative distribution curves for 12km and downscaled 1.5km models against observed 28-station. island average

Mr Bertrand Timbal, CCRS, Singapore, summarised the impact of climate change on the Southeast Asian monsoonal seasons using results from Singapore's 2nd National Climate Change Study. He showed, that model representation of the regional geography around Singapore is particularly poor at 12km resolution, resulting in significant inconsistencies in the representation of the annual rainfall cycle over Singapore (in comparison to the GPCP and TRMM observational datasets). Based on all models' results for Singapore, no consistent trend in mean annual rainfall is noted. Sub-selecting GCMs based on their ability to represent the key observed features of the monsoonal flow in the region gives more robust signals of seasonal rainfall changes, with models projecting consistent decreases in rainfall during the Southwest Monsoon dry season and during the dry phase of the Northeast Monsoon (Feb). During the Northeast Monsoon (November to February), GCM representations of the cold surges explain the wide range in seasonal rainfall projections. Across 25 CMIP5 GCMs, there is no clear consensus on how the frequency and duration of cold surges will change; however, most models do agree on an increase in extreme rainfall (95th percentile rainfall) under RCP8.5, which will have important implications on flood adaptation planning in Singapore.



Bertrand Timbal showed that the range of projections of extreme rainfall increases during cold surges, the main driver of the range of future projections of extreme rainfall during the NE monsoon across CMIP5 GCMs

3.3 Day 3 Presentations: Applications of Climate Change Projections in the Impact Community

3.3.1 Summary

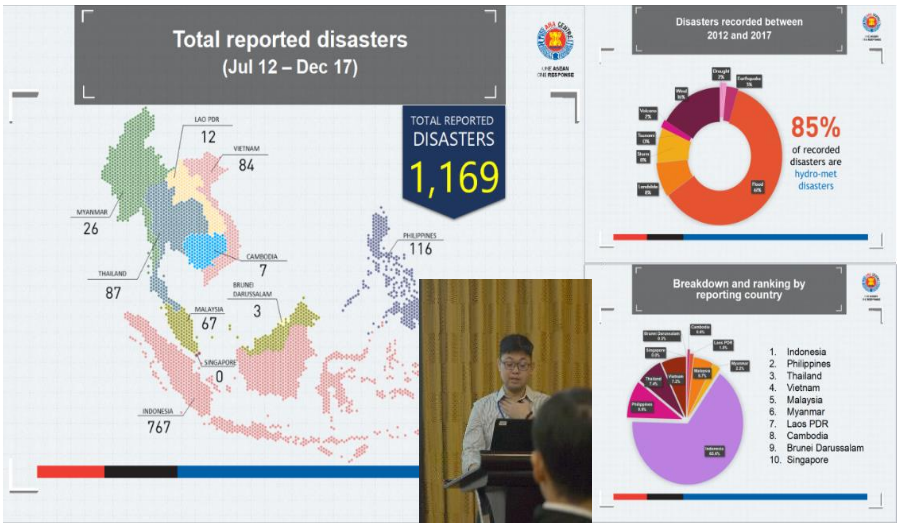
A total of eight presentations provided a rich picture of the use of the climate change information across the Vulnerability, Impact and Adaptation (VIA) community in Southeast Asia. Presenters were from different backgrounds ranging from local government agencies and advising committees to regional economical groups and disaster managing groups covering a wide base of end users.

Examples of local community engagement were covered by two Singaporean government agencies (Public Utilities Board (PUB) and Ministry of National Development (MND)) as well as India-based International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Across these presentations, the importance of the relationship between the science provider and the VIA user was reinforced. The outcome of this linkage does influence future policies. Such communication cannot be immediately successful and requires iterative efforts. Across the various examples, it also become apparent that both short term and long term planning are intertwined—a good preparation for future climate change cannot be dissociated from an on-going concern about the implications of climate variability; a similar motivation to benefit the users underpins both activities.

Other presenters in this part of the workshop dealt with regional community engagement (e.g. The ASEAN Coordinating Centre for Humanitarian Assistance (AHA) Centre and the Global Water Partnership for Southeast Asia (GWP-SEA)). Other institutions have a narrower geographical focus, such as the Mekong River Commission (MRC), which covers the region along the Mekong River, and the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES), which has some localised activities within Southeast Asia. Finally, the workshop benefited from an example outside the region: the Pacific-Australia Climate Change Science Adaptation Planning (PACCSAP) project as well as a similar cross-national project for Southeast Asia, the Regional Climate Consortium for Asia-Pacific (RCCAP).

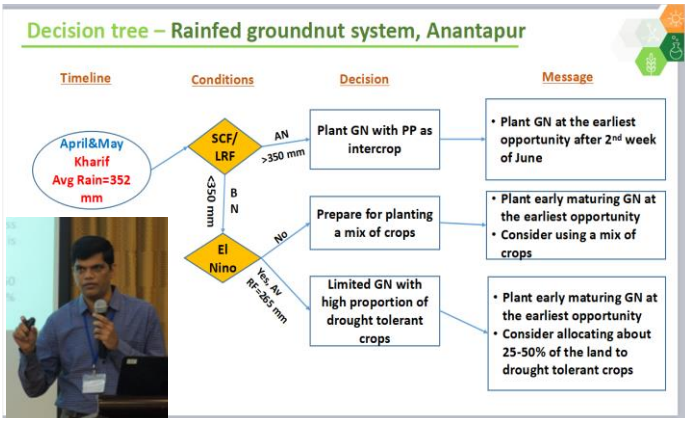
Across these examples, different aspects were reviewed: the direct usage of the climate products, recommendations and training for the communities, and also products for the potential end users to take up. It was highlighted that many institutions across the region tasked with handling climate data are not well equipped do to so, and it was suggested that climate scientists should focus on practical solutions. The gap between the end users and the scientists was recognised and these institutions shared on their aim to bring the products to the end users in an easily interpretable format. Community involvement in the development process allows for a product that is better suited for the user needs. As multiple regional communities face similar scenarios and demands, a product suited for all would better utilise the research resources and impact a greater community. Other than specific products and recommendations, providing training and online learning resources would help build a community that appreciates and understands the usefulness of the climate studies.

Mr Qingyuan Pang, AHA Centre, Indonesia, presented how climate data is used in the disaster risk reduction industry, and also AHA Centre's plans of promoting the use of such data in future policy. Mr Pang explained that AHA Centre was set up due to the increase in disasters in the ASEAN region, with Indonesia currently being the most affected country. Of all the recorded natural disasters in the region, hydro-meteorological disasters were the most common, making up 85% of the disaster record. Mr Pang presented a weekly disaster trend for 2012 to 2017, showing fewer recorded events from April to October, coinciding with the climatologically drier period for Southeast Asian region and therefore resulting in fewer flood incidents. Mr Pang recognised that drought events may be under-reported, and that a tendency toward under-reporting of disasters by some countries may be due to language barriers. Mr Pang iterated that AHA Centre did not have the capacity to conduct detailed climate studies. Nevertheless, the impacts of climate change to ASEAN region is of concern to the Centre, particularly in the following four sectors: health; food and nutrition; water, sanitation and hygiene; and early recovery. Mr Pang outlined the use of climate models by the Centre to first improve understanding of risks and impacts to response operations, next to guide disaster risk reduction in recovery and rehabilitation planning, and subsequently to influence resource planning and disaster risk reduction. Mr Pang noted that AHA Centre also understands the importance of information sharing as it currently maintains two platforms for knowledge sharing: ASEAN Science-based Disaster Management Platform (ASDMP) for regional disaster-related research publications as well as the listing of disaster events, and the annual ASEAN Risk Monitor Report (ARMOR) for comprehensive analysis of disaster risk and trends, including sharing of the latest research initiatives, and to foster collaboration among the ASEAN Member States and relevant stakeholders



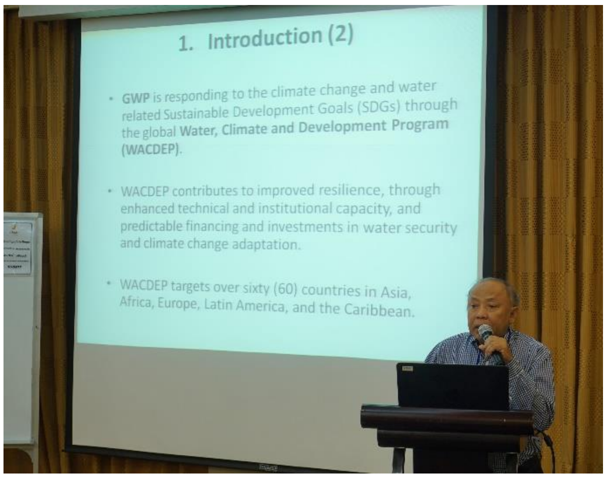
Qingyuan Pang presented on the experience of AHA Centre in managing impacts from climate-based disasters. It was shared that a total of over 1000 disasters were reported from July 2012 to December 2017, with 85% being hydro-met disasters.

Mr Dakshina Murthy Kadiyala, ICRISAT, India, discussed the usage of climate studies to assist agriculture groups in India in implementing more robust and efficient crops studies. India is highly dependent on the agricultural industry, with rainfall an important factor for the survival of the farmers. Examples of how climate science was used to benefit the farmers in both the short and long term were presented. In both cases, challenges arise from the high temporal and spatial variability of rainfall. Mr Dakshina discussed the management of crop systems in response to climate variability, with tactical approaches for season-specific cropping and management strategies based on long term weather data and crop models. In one study examining the use of climate data in developing cropping strategy, La Niña conditions were identified as being favourable for peanut and medium-duration pigeon-pea intercrop. Mr Dakshina demonstrated a decision tree to assist farmers in making crop decisions, which included consideration of starting climate conditions, timelines and updated rainfall conditions, and forecasts, to guide farmers on what to prepare and do next for a favourable yield. Longer term strategies and adaptations measures by ICIRSAT were also discussed. These included identification of vulnerable hotspots to climate change, application of existing knowledge on crops, soil and water management innovations, development of high yielding 'climate ready' crops, and the diversification of crops system and sources of livelihoods. Data from India Meteorological Department was used together with AgMERRA and CMIP5 for the analysis. Adaptation packages were promoted to the farmers in various regions based on bio-physical and socio-economical components. These plans are part of a future farming system with adaptations to fit the individual region, co-designed and co-developed with national and regional stakeholders, with the aim of developing regional-specific solutions to fit local challenges.



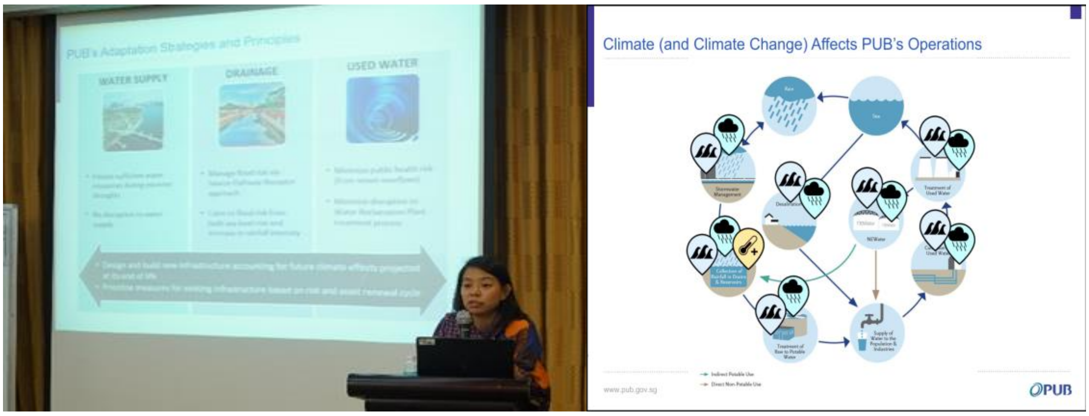
A decision tree to assist farmers in making crop decisions

Mr Sutardi Sudirman, GWP, Southeast Asia and IWP, Indonesia, presented the role of GWP-SEA and shared examples on the planning and policies done by IWP. GWP aims to provide sustainable development goals on water management through the global Water, Climate and Development Program (WACDEP). WACDEP aims to improve resilience in water security, targeting over 60 countries globally and supporting countries in implementing their national adaptation plans to achieve Sustainable Development Goals. WACDEP for Southeast Asia was developed with a focus on the water sector with flood and drought identified as the major concerns due to climate change. It aims to facilitate the proper implementation of flood and drought management in national adaptation plans to improve the resilience in the management of the water sector. An example of flood policy in Indonesia was discussed by Mr Sutardi, who noted the shift from flood control to flood management by the Indonesian government. Multiple studies were made by IWP to develop a framework for climate resilience, water resource investment planning, guidelines for a system of rice intensification, and development of capacity, such as through training modules for water managers. Mr Sutardi identified the challenges in formulating and implementing the strategies for relevant national adaptation plans. Data accessibility was an issue, with data collection a challenge given the diverse data type needs required by various sectors. High resolution and extensive coverage of data were identified as missing pieces to conduct more reliable analysis and review of



Mr Sutardi discussing the management of water disasters existing water infrastructure. For long-term planning, such as in the review of current hydrologic parameters utilised in the design of water resources infrastructure in response to future changes in rainfall characteristics, Mr Sutardi recommended that climate scientists be involved in the process. Water resource management was identified to be the main user of information regarding climate variability, with data collection and downscaling methodology targeting this sector.

Ms Minghui Teo, PUB, Singapore, described the uptake of Singapore's national climate change projections in term of policy decision for water management across the island. PUB is Singapore's sole water agency and manages the complete water cycle in Singapore, from storm water management, supplying drinking water, and the collection and treatment of waste water. Hence they look to adopt a holistic approach towards water management policies in response to climate change.



Teo Minghui from PUB, discussed Singapore's strategy and plans to adapt water management in Singapore to climate change

Ms Teo shared specific case studies and discussed the working experience between the science provider, MSS-CCRS, and PUB, identifying the different challenges posed by climate change to PUB operations. Water demand management relies on four sources of water: water from local catchment, imported water (from Malaysia Johor river through an international agreement between Malaysia and Singapore), NEWater (recycling), and desalinated water. NEWater involves a deep tunnel sewerage system implemented to meet Singapore's long term needs for used water collection, treatment, reclamation and disposal. Ms Teo highlighted two different areas of concern: impact of climate change on water resources yield (relying upon a 50-year projection based on a rainfall-runoff model using the spread of rainfall projections from the 9 GCMs included in Singapore's Second National Climate Change study) and the impact on drainage design (using projections of changes in the 15 to 30-minutes peak rainfall for drainage design; a major challenge due to the high temporal frequency: i.e. below daily timescales). She also mentioned the impact on water quality. Sea level rise is also a major concern associated with climate change: intrusion of salt water in reservoirs, coastal inundation, and inland flood risks based on a combination of sea level rise and future projections of higher rainfall, all of which challenge the current structural adequacy for reservoir tidal gates and dam/dykes. PUB recognised the uncertainty involved in the assessment of climate change effects and accounted for it in their policy planning phase. Workshop participants were impressed by the holistic approach presented by PUB and saw it as a potential model for the region. The presentation also serves to underscore the importance of letting stakeholders define their own "risk appetites" and deal with projection uncertainties from their own perspective (e.g. PUB decided to plan for the worst case impacts to the water supply).

Mr Jack Huang, MND, Singapore covered the general policies and directions taken across various agencies in Singapore towards climate change. Resilience is the main focus of MND in tackling climate change. Mr Huang explained that Singapore uses a four prong approach strategy: reducing our carbon emission in all sectors, adapting to impacts of climate change, harnessing green growth opportunities, and forging international collaborations. MND is part of the Resilience Working Group (RWG) against climate change, involving 19 agencies in total under the direct chairmanship of Singapore Deputy Prime Minister whom is chairing the Inter-Ministerial Committee on Climate Change (IMCCC). Singapore does not face major natural disasters, the challenge instead is to build resilience in face of climate change consequences: rising sea level, increase in extreme rainfall, and temperature rise. Due to the uncertainties of future changes, resilience needs to be thought through with flexibility. There is a need to prioritise adaptation measures to avoid the pitfalls of over-planning as a result of over-reliance on set metrics. MND focused on 6 main priorities: coastal inundation, water management and flood minimization, protecting our biodiversity and greenery, strengthening resilience in public health and food supply, keeping essential services running well, and keeping our buildings and infrastructure safe. Public engagement is an important part of building up the resilience to climate change as everyone has a role to play, with the government having the leading role.

Jack Huang from MND covered Singapore's strategy and plans for climate change

Mr Nguyen Dinh Cong, MRC, Vietnam, described the working of the MRC an inter-governmental organisation dedicated to the sustainable development of the Mekong River.

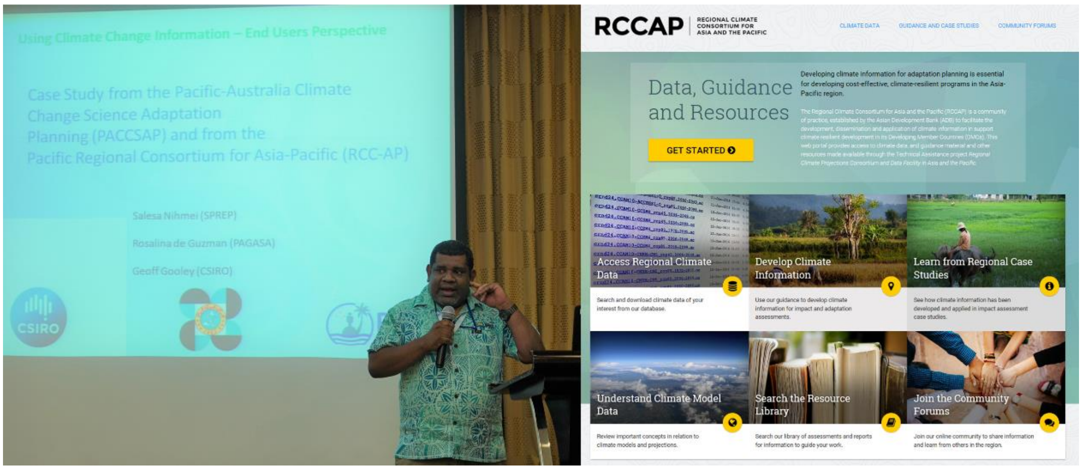
Ding Cong Nguyen informed the workshop on the strategy and adaptation plans by MRC

Mr Nguyen explained that the lower delta basin countries are the most vulnerable to climate change; a basin-wide assessment is required especially as the group of countries involved

(Cambodia, Laos, Thailand, and Vietnam) have little adaptive capacity in response to climate change. A top-down approach was used to assess the impacts of climate change on the lower basin, its vulnerability and the adaptation options, as well as their implementations. Mr Nguyen explained the steps to define the climate change scenario: starting with the review of the existing downscaling approaches, followed by selection and collection of climate change projection dataset and the usage of a statistical tool (SimCLIM) to derive numbers. A selection of GCMs and an analysis of the scenario uncertainty was done and proposed to member countries and for their agreement. The basin wide assessment aimed to provide the impacts of potential future climate changes on water resources and related sectors, with assessment of various components such as: hydrology, flood, drought, ecosystem, biodiversity, food security, hydropower and other socio-economic factors. The Lower Mekong Basin countries approved a set of strategies to address climate change risks and strengthen basin-wide resilience. These strategies are expected to help bring the climate change issue into the mainstream of regional and national policy and planning, increasing regional cooperation and partnership on adaptation, and preparing transboundary adaptation in particular to finance adaptation strategies. While monitoring, data collection and sharing is the responsibility of all member countries, the MRC also plays a role in outreach and capacity development for adaptation planning.

Mr Jothiganesh Shanmugasundaram, RIMES, Thailand, explained that his agency has an objective to enhance availability of climate information to guide sectoral agencies in adaptation planning. For Mr Jothiganesh, RIMES acts as a bridge between climate scientists and regional stakeholders, helping both parties appreciate the very different requirements for the various users. Examples of case study completed by RIMES for the Maldives and Sri Lanka were presented. The threat of sea level rise was identified as the main risk to Maldives, but the project eventually identified that sea surface temperature increase was also a major risk as it impacts fisheries and coral health. RIMES organised training workshops to inform and educate the stakeholders on the use of the information and tools. For Sri Lanka, the projection of reduced rainfall and higher drought risk to the northern dry zone led to water balance studies, aiming to divert water from Mahaweli river to the dry zone and address water scarcity issues. Climate Data Access and Analysis System (CDAAS) is a one-stop easy to use portal for accessing, analysing and visualizing different global climate model output with focus on Myanmar, Pakistan and Sri Lanka, aiming to link climatologists, sectoral experts and policy makers. RIMES contributes to capacity building (e.g. stakeholder meetings); this is part of the overall aim to bridge the gap between climate scientists and stakeholders: RIMES sees itself as the middle man.

Mr Salesa Nihmei, SPREP, Samoa and **Ms Rosalina de Guzman**, PAGASA, Philippines presented case studies from PACCSAP and RCCAP respectively. Mr Salesa explained the work in PACCSAP to train people involved in agriculture through regional workshops and also sending them to WMO course to improve their understanding of the use of probabilities in climate studies and projections. Guidance material is being prepared on climate change information for the Pacific and scheduled to be released later in 2018 to engage decision makers on the use of climate change information. Ms Rosalina explained the role of PAGASA in RCCAP. She presented a number of case studies available in the RCCAP website including presentations from end-users on the usage of the information. Training material is also available on the website to build up capabilities in the use of climate data and provided information to engage end users.



Case study from PACCCAP by Salesa from SPREP (left), and demonstration on the usage of the RCCAP website (right) by Rosalina de Guzman, from PAGASA

3.4 Day 4 Presentations: Future Developments in Climate Change Science

3.4.1 Summary

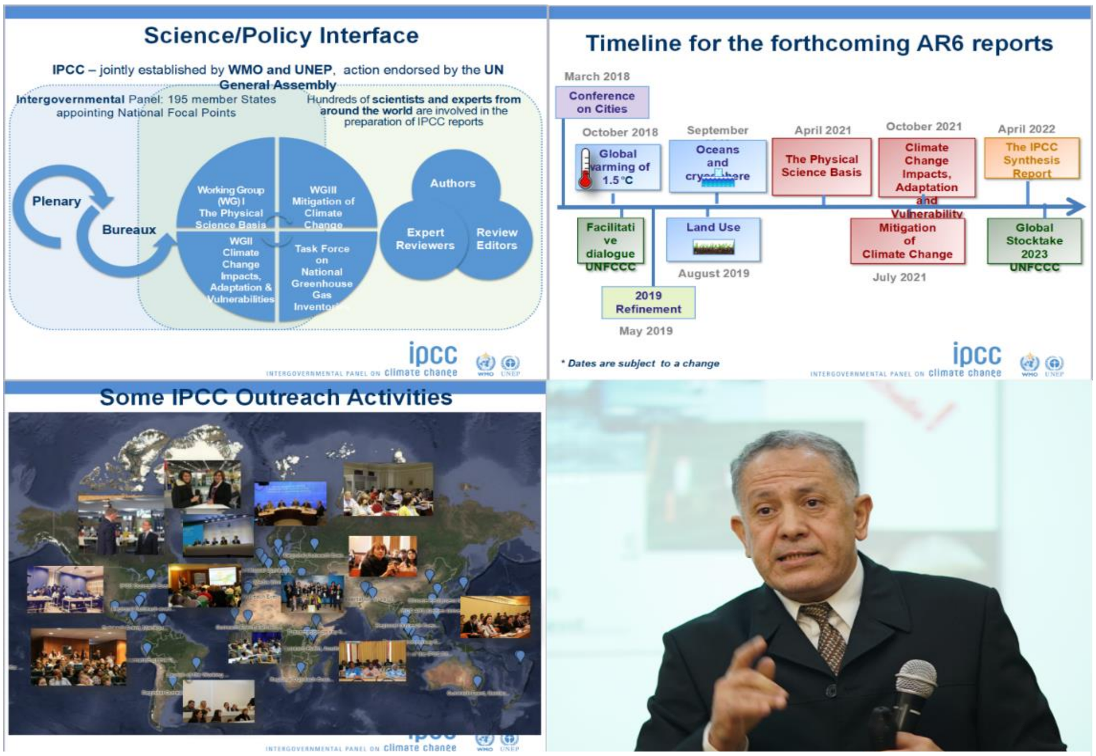
On the final day of the workshop, presentations focused on likely future developments for climate change science: improving the quality of the climate products and further developing user engagements.

Climate Product Quality: In the words of the presenters, improving the quality of the climate products is about making use of more information and in particular, a larger number of host models to increase the coverage of the uncertainties from within a particular emission scenario, to deliver outputs with different resolutions for different scientific issues. This was seen as necessary to produce useful climate products for the end users. Participants agreed that collaboration between scientists within the region would accelerate the process towards standardized high quality products whilst making better use of national resources. This recommendation for enhanced regional organisation and cooperation was reinforced by the vision provided by the IPCC secretary, Mr Mokssit, who explained how the next CMIP6 phase will be the most intensive exercise yet, involving more models and experiments, while the models themselves have continued to be improved are expected to deliver a much more realistic representation of the physical world. These technical advances will allow for the required emphasis on regional analysis and extreme weather, both of which are in high demand across the region. Nonetheless, prior user engagement in the development of climate products is still necessary and will only compound the final benefits of the products. This can be achieved through tailored focus studies to identify and effectively utilise resources available for each specific region and industry of concern.

User Community Engagement and Services: User engagement was identified as a necessity as the products generated by climate research are to be transited to the users. A regional coordination framework for promoting end-user engagement could be set up to efficiently deliver such engagement while fully leveraging on IPCC research work. This framework would push developed climate products to the appropriate users and allow for continuous research and progression. The understanding of the user requirements should not be underestimated as scientists are not fully exposed to the work of the end users. A commitment to organising user engagement and education workshops is required to build holistic understanding and knowledge exchange. It was also pointed out that having designated individuals to bridge the gap between scientists and end users (i.e. applied scientists) could be very valuable. It was stressed that innovative communication tools are required to ensure the propagation of the research/material/climate information, such as: user-friendly websites, step-by-step education materials, etc. These tools could help to introduce the public to the complexity of the climate science and the various climate products available. Usage of social media to reach out to the public could also increase awareness of climate change and eventually, the usage of the products as well.

Finally, it is clear that the two issues above are interlinked—the progression of climate projection quality and its continued relevance is dependent on user engagement and involvement. The quality of the products needs to be improved with increased collaboration between scientists across the regions, so as to achieve a meaningful and standardized format to target the similar needs of end users across the region. This is where a regional coordination framework would be highly useful.

Mr Abdallah Mokssit, IPCC secretary, Switzerland, presented IPCC plans for the next phase of delivery of assessment reports. Mr Mokssit reminded the audience that the IPCC operated at the interface between science and policy, it is an intergovernmental panel relying on groups of scientists and experts around the world, together they generate the IPCC reports. Some key and strong messages have now emerged from the IPCC assessments: 1) *the human influence on on-going climate change is undisputable*, 2) *more disruption to the climate system equal more risk for the human civilisation* and 3) *it is possible to curb the problem in the near future by reducing emissions*. In their sixth assessment cycle, the Assessment Report 6 (AR6) are expected to be delivered in 2021 across the 3 working groups with the synthesis report delivered in 2022. The cycle has already started with a methodology report update and special reports (e.g. targeting a 1.5°C world). Mr Mokssit noted that the work on AR6 is highly dependent on the Coupled Model Intercomparison Project (CMIP), currently in sixth phase. This is especially so for their Working Group 1 which deals with physical science basis of climate change. Mr Mokssit stressed the importance of CMIP in making multi-model outputs publicly available in a standardized format for the wider community. The uptake of CMIP is increasing due to the need to address an ever-expanding range of scientific questions arising from an increasing number of research communities impacted by global climate change.

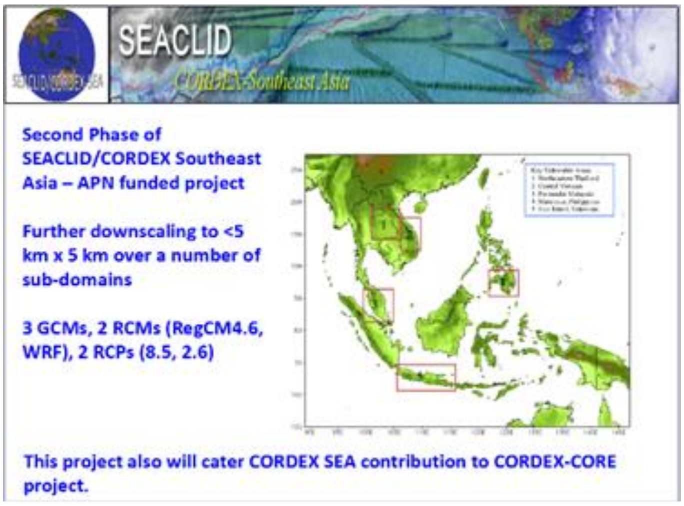


Abdallah Mokssit explaining on the role of IPCC in interfacing science and policy as well as the focus and challenges for the next phase of the IPCC AR6 and CMIP6 dataset. Outreach and engagement is also high on the priority list of IPCC

The sixth phase (CMIP6) aimed to address this through a more federated structure, new models of higher complexity and also higher resolution models. CMIP6 which started to be populated as far back as 2013, is completed in staggered stages and is expected to be on time for use in AR6. End user engagement is of highest importance from the IPCC perspective. IPCC is looking toward putting more emphasis on regional analysis with input from dynamical downscaling and a focus on extremes. Regional coordination and framework on end user engagement was encouraged to achieve this. Mr Mokssit also stressed the contribution that regional scientists can make to the IPCC reporting by contributing to the published literature in due course.

Mr Fredolin Tangang, UKM, Malaysia and CORDEX-SEA coordinator, presented the future plans for CORDEX-SEA. The first phase was completed in 2018, and the second phase of CORDEX-SEA is underway. While it is difficult to increase the full CORDEX-SEA domain due to its sheer size, further downscaling to 5km is proposed over a number of sub-domains. The new information expected from the higher resolution simulations are in response to user demands and emerging scientific challenges: studies on urban cities, wind energy harvesting and water resources.

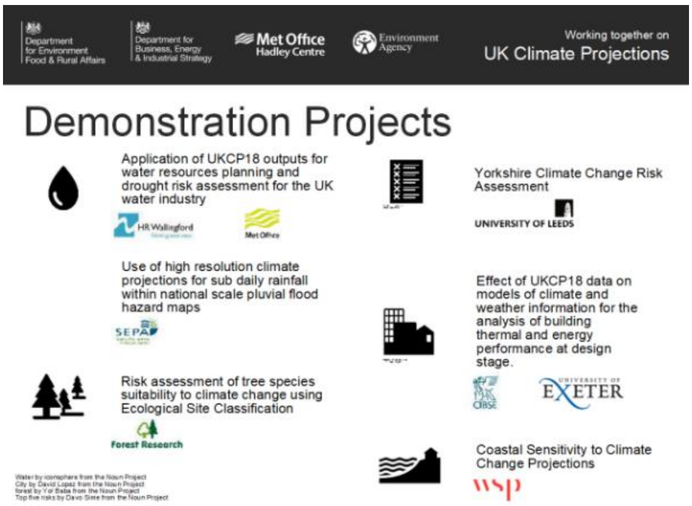
Fredolin Tangang shared with the audience CORDEX-SEA future plans



Sub-domains targeted for fine resolution simulations as part of the second phase of CORDEX-SEA project

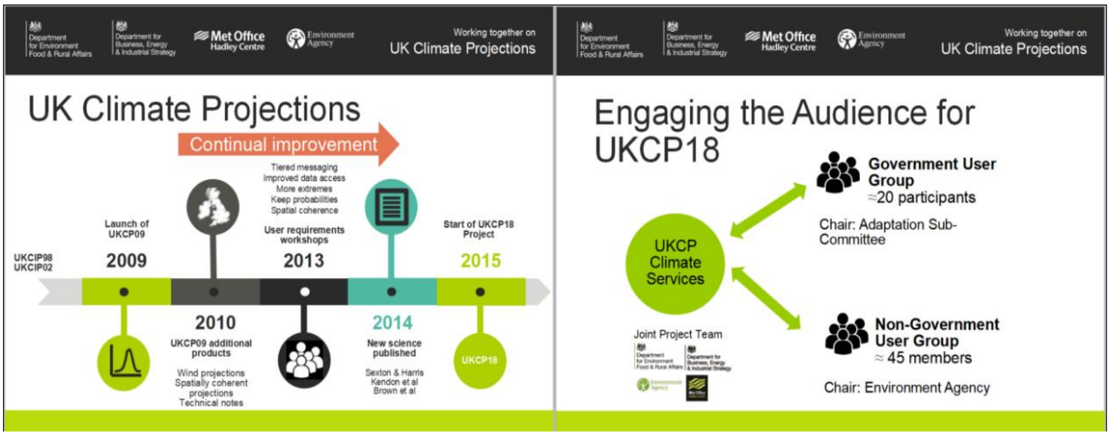
In the meantime, Mr Tangang explained the on-going global effort across the 14 CORDEX domains covering all the continents (of which CORDEX-SEA is one) to deliver consistent information for the AR6 regional atlases based on 3 GCMS, 2 RCMs, and 2 RCPs (8.5, 2.6); this work is completed by resources outside the region. To complete this external work meaningfully, and extend the matrix of GCMs/RCMs for various RCPs, engaging more partners across the region is necessary.

Ms Nicola Golding, UKMO, UK presented the latest national climate projections for the UK. The goal of UKCP18 is to produce and deliver an updated set of climate change projections that are scientifically authoritative and coupled with end products designed to maximise the utility of the projections. Ms Golding explained that UKCP09 formed the basis for climate risk assessment and was widely used by the government for National Adaptation Plan, with other sector specific usages: e.g. regulators using it for flood risk assessment and water resources management, other usages in building design or on social vulnerability. UKCP18 will build up on this foundation and will add an improved treatment of uncertainty and risk making use of 20 spatially coherent realisations with *"perturbed*



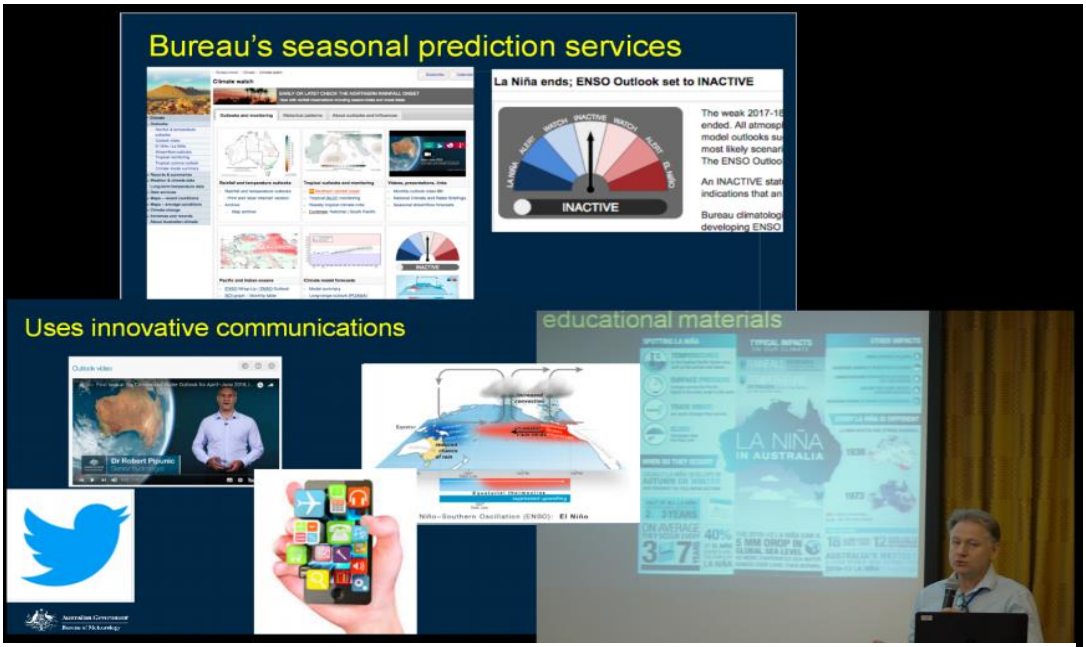
Demonstration projects to engage potential users as part of UKCP18 engagement strategy.

physics". Physics in both the global and regional models have been improved for this generation of projections. Significant effort was placed in engaging the audience for UKCP18, with government user groups and non-government user groups invited to "user requirement workshop" in order to deliver a set of useful products (the UKCP database). UKCP18 will also produce 1 year means rather than 30 year means, allowing more natural variability within the climate change projection to be captured for the benefit of adaptation studies. The increase in resolution both spatially and in time is clearly in response to user needs emerging from the workshops. Demonstrations projects have also been planned for the end users to engage the users and demonstrate the potential uses of UKCP database. This aims to bridge the gap between the users and the climate data scientists and also to enhance the user experience of the climate information. UKMO also recognised that UKCP18 is unable to cover everything wanted by the users, hence one major component of UKCP18 is understanding and encouraging future funding to meet the more complex needs of the users.



UKMO's climate projection project's timeline (left) and the engagement of audience for UKCP18 (right)

Mr Scott Power, BoM, Australia focused on the climate change projection services that Australia needs, given that the BoM, alongside its longstanding research endeavours, has now developed service delivery expertise and is looking to expand toward providing complete climate services. Currently, web-based materials, associated reports and tools for climate data analysis are some of the services and products produced to disseminate climate change information. BoM is seeing a huge demand for projection information in Australia as climate change is becoming an increasingly critical issue, coupled with the strong impact of naturally occurring climate variability. Mr Power pointed to existing BoM seasonal prediction services to facilitate the management of this variability. An example highlighted was the Bureau's seasonal prediction services, which make use of infographic figures to portray climate data and trends, facilitating easy interpretation by the users. A large range of educational materials at different levels of complexity is also available, and user engagement is performed with innovative communication tools through social media and videos. Continual effort on these platforms is needed to actively engage a large user group. Thus, education, training and engagement are major components of the future development plans. In light of this, Mr Power commented that providing climate services is not just about providing climate projections, as the credibility of projections is in some ways dependent on the ability of climate science to explain what has already occurred. The documentation and explanation of observed trends and the provision of scientific understanding on the reasons behind the changes can be effective to improve understanding of the science that goes into climate projections. This can help users understand and make use of the projections for mitigation decisions and adaptations, and also build confidence in the use of projection services. Stakeholder engagement of stakeholder is crucial, and identifying and prioritising stakeholder relationships is a major and necessary challenge. However, effective engagement could be resource-intensive and require multi-year sustained relationships.



Scott Power explaining BoM services and the different modes of communications exploited

Unable to attend the last day of the meeting, subsequently**, Mr Geoff Gooley with contribution from Mr Michael Grose**, CSIRO, Australia, provided additional information on future plans for producing the next generation of climate change projections for the Australian region. CSIRO has been releasing national climate change projections regularly since 1992, typically shortly after each IPCC assessment report and CMIP experiments, with the current suite having been released in 2015. These latest projections were developed over approximately five years, and were informed by extensive stakeholder engagement activities. User support, website maintenance and outreach activities are on-going at a relatively modest level through the National Environmental Science Program's Earth Systems and Climate Change (ESCC) Hub. As the IPCC Sixth Assessment and CMIP phase 6 (CMIP6) will be delivered around 2021, planning for the development of a new suite of climate change projections are set to begin now in order to ensure that current and future decisions are based on the most up to date information and evidence provided by AR6 and CMIP6,

Under the guidance of the NESP ESCC Hub, a range of key stakeholders including researchers and government policy-makers/end-users have jointly proposed a staged approach to the co-production of 'next generation' climate change projections for Australia: as follows:

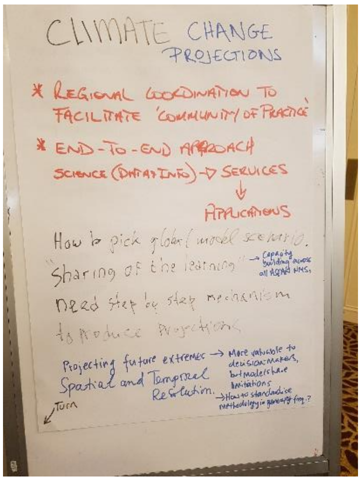
Stage 1: NextGen v1.5, to be delivered in 2020/21, involves an enhancement of the functionality of existing projections and the tailoring of content for current needs already identified, and increased knowledge brokering to deliver projections. This stage would also need to conduct the research and modelling required to build towards Stage 2.

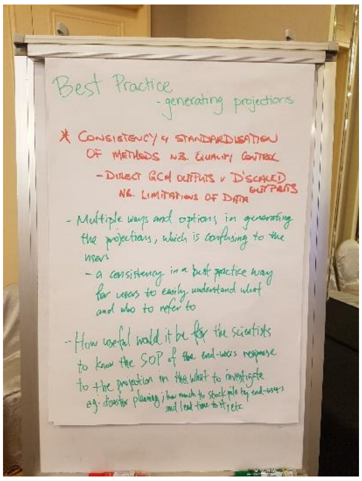
Stage 2: NextGen v2.0, to be delivered by late 2023/2024, involves a significantly updated set of national climate change projections based on new science, the imminent IPCC assessment, and CMIP6 and CORDEX2 climate model outputs (including Australian contributions). Enhancements and improvements to products and services from Stage 1 will be maintained, including the upgraded knowledge brokering service. All new projections will be put into context of previous projections, so that users can easily understand what is new and what has changed.

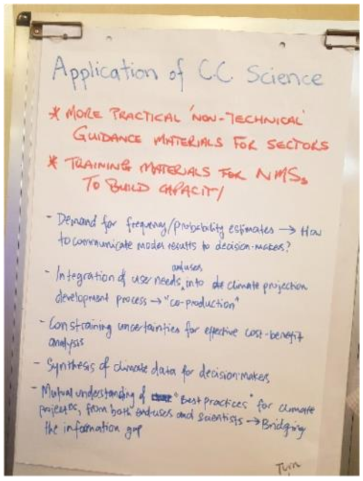
Stage 3: Ongoing development and delivery from 2025-2029, involves ongoing delivery and enhancement of national projections in Stage 2, planning and delivery of further enhancements and mainstreaming of climate change products and services in Australia.

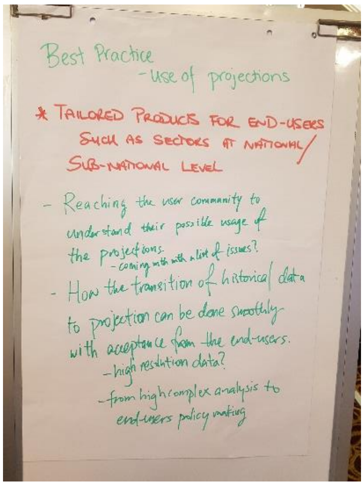
Under the NextGen programme, existing and new web tools on www.climatechangeinaustralia.gov.au and linked websites will be developed and maintained, and better integrated with other platforms and geospatial datasets, to ensure tools remain relevant, useable and updated. Ongoing monitoring and evaluation will ensure that strengths and weaknesses are identified and managed, and outcomes are achieved. Key elements of the proposed strategy would include governance, a research plan with outputs that target high priority outcomes and impacts, a stakeholder engagement plan, a communication plan, a risk management plan and a monitoring and evaluation plan.

3.5 Consensus Emerging from the Break-up Discussions









Selection of issues and discussion points raised during the Workshop regarding the production and application of climate change projections.

Break-up sessions were conducted on Day 3 and 4 of the Workshop to facilitate discussions on key issues relevant to the production and use of climate change projections for the region. The discussions centred on guided questions prepared in advance, with feedback from participants noted on flipcharts. Participants were divided into groups to encourage active participation. In the first break-up session, cross-sectorial communication was encouraged by ensuring each group included a wide range of regional and national expertise. In the second break-up session, groups were divided according to sectorial expertise to enable more focused discussion.

Discussion points were designed to help participants begin to identify recommended policies and processes, facilitating the final discussion on best practice guidelines conducted at the end of the Workshop. With regards to the science of climate projections, participants were asked to consider:

Q1. What climate projections does Southeast Asia have and need?
Q2. What are the key gaps in the process from producing climate projections to applying them to adaptation policy? How can we address these gaps?
Q3. How can advances in climate change science be incorporated into regional and national policy?
Q4. What strategies could be employed to improve the quality and coverage of projection information for Southeast Asia?

With regards to the application of climate projections in policy and adaptation planning, participants were asked to consider:

Q5. What climate projection products have been useful, and what else may be needed?
Q6. What may be restricting the wider usage of climate projection information?
Q7. What needs to be done in the region to facilitate the application of climate projection information? Are there good case studies that can be adapted for the region?

The responses emerging from these various discussions are gathered in the 4 sections below, organised based on the question theme (e.g. Q2 and Q4, Q3 and Q6 and Q4 and Q7).

Break up groups discussing key issues during day 3 and 4 of the workshop and then presenting key findings during plenary sessions

3.5.1 Existing Climate Projections (Q1)

Participants emphasised that the situation in Southeast Asia has improved noticeably over the last 5 years, with the amount and quality of climate products available having grown considerably. The key issues now emerging now are 1) for each ASEAN country to fully utilise existing data, which may not necessarily reside in their country (e.g. data from CORDEX-SEA) and 2) the availability of data (which in some cases may be restricted or difficult to share). These problems may soon be solved, with several comprehensive web-based portals currently being developed to serve the broad needs of the regional community (e.g. the existing RCCAP, the observation data portal SACA&D and the CORDEX-SEA related and newly launched SARCCIS).

It was noted that in contrast to climate change projections, the same issues of regional collaboration for seasonal climate predictions was solved through the development of a Southeast Asia RCC-Network (SEA RCC-Network) for predictions, monitoring and data provisions on sub-seasonal and seasonal timescales. The SEA RCC-Network was established under the coordination of one country, but with several ASEAN countries involved in the development of the various components crucial to its mission. However, it should also be noted that the impetus to produce climate change projections varies across the region in line with the current sensitivity and exposure to climate variability experienced by the local community. This means that what is of interest and how to apply the science varies greatly across ASEAN countries.

As part of the progress registered regionally in delivering climate change projections, it was noted that the limitations of climate models are now better understood and communicated. We are starting to see the emergence of strong and sustained relationships between research groups delivering climate change information and users (e.g. the relationship in Singapore between the Centre for Climate Research Singapore (CCRS), a centre dedicated to climate research, and PUB, Singapore's National Water Agency and a user of the science, presented by Minghui Teo).

In summary, while extensive information related to climate change science exists, further action is required to provide authoritative guidelines on the use of this information at a regional level. However, whilst there is undeniable benefit to collaborating at the supra-national level, particularly in the advancement of regional climate change research, in the application of climate change science there is often an impetus to provide localised or sector-specific information to state-level authorities (e.g. provincial/local governments), which may be incompatible with a high-level centralised regional approach.

3.5.2 Existing Gaps in the Climate Change Science and Products Used (Q2 & Q5)

As a preamble, it was noted that a significant gap remains between generating climate change projections and using them to make policy decisions, in particular state of *low use* or *no use* of the projection data.

With increasing computing power and the use of many different RCMs across Southeast Asia, products with high spatial resolution on the order of 12 to 40 km grid spacing are now commonly generated. However, these resolutions are still too coarse for many parts of the Maritime Continent, particularly archipelagos of small islands with complex topography. Furthermore, convective thunderstorms, which are the most important weather phenomenon for the tropical region, also cannot be captured. RCMs can now be pushed to *convection-enabling* resolutions (in the vicinity of 5 km, in which convection need not be parameterised, and can be captured by the model's core dynamics) and even *convection-resolving* resolutions (in the vicinity of 1 km). At these resolutions, significant improvement in model representation of the observed climatology is noted, but computational expense severely limits its potential application across the ASEAN region and will continue to do so for the foreseeable future. Thus collaborative approaches across the region focusing on sub-domains of critical importance (e.g. over dense megacities, or areas of central economic activity) appears mandatory to achieve further progress.

Being at the forefront of current scientific development, the added value from these simulations at very high resolutions is yet to be demonstrated. It is also at these fine resolutions that projections from dynamical downscaling (RCMs) can be contrasted with projections emanating from statistical downscaling (empirical relationships between large-scale forcing and local scale responses established based on observations). This offers the potential for very valuable research, particularly in the understanding of climate mechanisms in a warming world. However, at present it was felt across the spectrum of participants present at the workshop that the additional downscaled products presented more of a challenge to interpretation of results than a useful contribution, given the lack of understanding of how to synthesise information from the various downscaling approaches, especially when the projections diverge. Information portals, such as the RCCAP project detailed by Ms Rosalina de Guzman, were acknowledged as valuable resources that could be leveraged upon to build understanding across the region.

The importance of climate variability and its associated societal impacts as a driver to the uptake of climate change information was noted earlier. However, current projection products provide little information on the intertwined problems of climate change and climate variability, which together will set the ultimate trajectory of future climate change, and in turn, the direction of adaptation plans. Estimating future climate variability starts from a good understating of historical climate variability, a concept not necessarily well-grasped by users of climate change information. It should also be emphasised that climate change itself will also change the observed climate variability (e.g. Scott Power's presentation on Day 2 on ENSO teleconnections in a warmer world).

Climate change will be experienced through climate extremes (as is climate variability at present); yet extreme indices commonly used are generic, and may not be well-adapted to the region of use and to the range of users across the VIA community. Developing the appropriate extreme indices is a scientific challenge, as users often demand very high temporal resolution (daily and sub-daily) products. These products can be computed but are not necessarily well-grounded scientifically. In a similar vein, the poorly-guided use of bias correction, while necessary to provide usable outputs by the VIA community, is also dangerous and may lead to erroneous outputs.

A recurrent deficiency in the current set of climate change projections is a lack of focus on the key phenomenon that global or regional models need to capture realistically. It was noted that while the evaluation of the Global Climate Models (GCMs) from which RCMs are forced is extensive, in particular to select the most appropriate GCMs, not enough is done to evaluate regional climate phenomenon in RCMs (e.g. monsoon onsets and duration, Madden-Julian Oscillation (MJO) propagation, diurnal cycle and land-sea contrast of the convection, as was presented by Ammar Bin Abdullah on Day 1). A more thorough examination of these issues across the regional scientific community would 1) enable the development of regional matrices commonly used across the community, 2) increase understanding of the biases in the models, 3) enable fine-tuning of the physical parameterisations used in models, and 4) increase consistency between the forcings from GCMs and the response of RCMs.

Additionally, the lack of coupled ocean-atmosphere RCMs, despite their relevance to some industries (e.g. fisheries) and also possible evidence of improvement in improved RCM behaviour when coupled, was also brought up during the discussion. Finally, a technical issue which surfaced was that the data format used by the science community (derived from using models with 4D fields) is challenging and not easily compatible with the VIA community, for which modelling is often a 1-dimensional problem (i.e. relying on excel spreadsheet and ASCII files).

3.5.3 Limiting Factors in Climate Change Projection Usage (Q3 & Q6)

As identified in the answer to Q1, the amount of climate change projections available within Southeast Asia has grown rapidly. For end users, it can be overwhelming (e.g. which data source to trust?) and raises the need for bridging expertise to synthesise the raw climate data into relevant and actionable climate change information for sector-specific use (e.g. the *Climate Futures* software developed in Australia, the role of RIMES in disseminating climate science, or the interaction in Singapore between CCRS as a climate change information provider and PUB as a user).

Discussions during the workshop had a strong focus on the relationship between science providers and users. Building this relationship is a complex undertaking that requires time to evolve and progress. In recognition of the complexity of the climate change science, incorporating climate education into this process is required (e.g. constant and targeted training), particularly to identify and separate the short term issues of weather and climate forecasting, with the long term projections of the plausible future climate. This in turn also requires educating users on the intricacy between climate variability and change. One of the goals of this education process is to create awareness of the complexity underpinning climate change science, whilst also innovating approaches to improve its accessibility to stakeholders.

Another important issue that needs to be communicated better is the uncertainties attached to the projections. One source of the uncertainties is climate change projections are built upon a spread of future possible scenarios hinged upon the global community's efforts to limit their future energy use. Apart from that, two major limitations are worth stressing: scientific (i.e. incomplete understanding of the climate system leading to a range of projections from equally competent climate models providing different mathematical solutions) and technical (i.e. limitations in computing resources, which necessitates the selection and prioritisation of emissions scenarios and the range of projections depending on). A clear descriptive labelling of emission scenarios is also recommended, such as RCP2.6 as the *best case* aligned with the commitments from the Paris agreement, RCP4.5 as an *optimistic* scenario and RCP8.5 as a *pessimistic* scenario but also at present the *business as usual* scenario.

These two issues together call for the usage of probabilistic information, which need to approached by the VIA community from a risk analysis perspective. A lot of two-way, continuous learning is required. This is where the risk profile and appetite is to be analysed from the user perspective and mapped against the range of projections delivered by the science. In essence, it requires the co-production of useful climate change projections at the interface between the scientific and the VIA communities. Such interactions involve knowledge exchange, which is far more complex than simple data exchange. From the VIA perspective, it should also be stressed that the adaptation must be perceived as dynamic and flexible in order to incorporate scientific development and uncertainties, though we should also not discard good VIA studies which are based on older model simulations (e.g. CMIP3) as the new set of climate projections based on more advanced GCM simulations (CMIP6) are becoming available (i.e. Abdallah Mokssit, IPCC secretary presentation on Day 4).

The suggested process emerging from these discussions is to deliver, alongside the projections products themselves, a big picture vision about what climate change means. Some important things to avoid were also identified, such as the dumping of unsynthesised projection data and their uncertainties (these need to be explained and mapped against the unique risk profile of the user), technical discussions on the downscaling methodologies (though an important discussion, it should be solved further upstream from the interaction with the users) and any unnecessary technicalities (e.g. usage of acronyms) as well as differences in interpretation of the common language. Overall, the process presents as a balancing act between scientific integrity and completeness of the projections versus the clarity of content necessary for their usability. There is no single solution to this process as it is dependent on the specific needs of the stakeholder.

However, it should be cautioned that these engagements are complex, targeted and may take considerable time. Therefore, strategic prioritisation is required and as per the previous discussion on the gaps in science, faced with this complexity, a supra-national partnership across ASEAN countries could be beneficial to ensure advances in any one country benefit the wider regional community.

3.5.4 Strategies for Facilitation across Southeast Asia (Q4 & Q7)

The diverse backgrounds of the workshop participants provide an opportunity to comprehensively review the institutional and cultural barriers preventing the Southeast Asian community to optimise development, interpretation and application of climate change projections, and to map the way forward.

A frequent barrier is the reluctance to openly share climate-related datasets. This is a counter-productive behaviour as institutions mutually benefit from the improvements in data networks, which is often the key limitation in the understanding of climate variability. This is particularly counter-productive for institutions whom scientific capabilities are limited by insufficient data network compare to the requirement to understand climate variability and for whom improvements will come through products which will encompass, alongside their own dataset, additional data from neighbours.

It was also noted that supranational exchanges and collaborations should not be limited to data but should extend to the information and knowledge derived from the data. A particular focus for workshop participants was the evaluation of GCMs. The same publicly available database of GCMs (currently CMIP5 and soon CMIP6) are evaluated by many groups across the region and it was noted that by-and-large the same features are evaluated. A standardisation of model selection criteria across the region was viewed as useful, especially considering it is the foundation of the climate change science. Models should be evaluated for their (i) representation of relevant climate phenomena, (ii) climate sensitivity, (iii) domain sensitivity, (iv) model biases and position in the uncertainty space and (v) degree of climate drift. Beside the evaluation and selection of the GCMs, the outcomes from the dissemination of the climate change information could also be shared to benefit the wider community (e.g. successful case studies for different sectors).

As a first step, to entrench regional collaborations, scientific papers with multiple authorship across the region could be published covering all the issues discussed above: (i) comparisons of gridded observations products covering Southeast Asia and their evaluation with in-situ measurements, (ii) climatological phenomena of importance across Southeast Asia that GCMs need to capture, (iii) framework to evaluate the performance of climate models across Southeast Asia, and (iv) successful studies at the science-user interface. The current listing is by no means exhaustive.

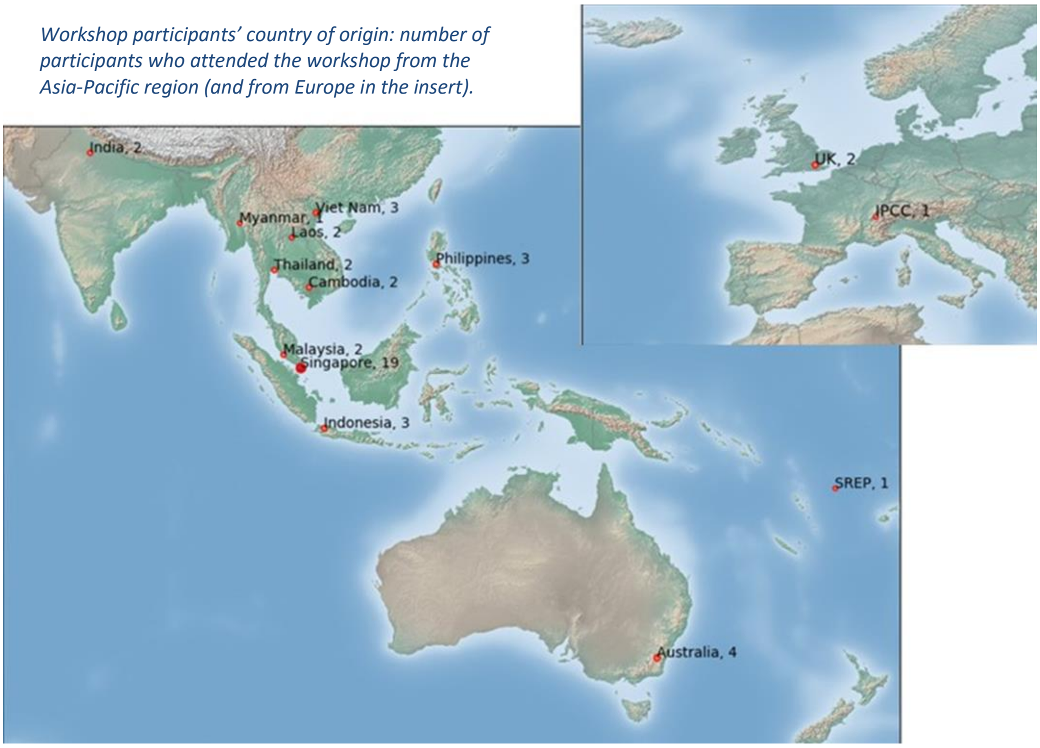
Beyond these small steps to improve collaborative efforts towards building robust regional climate change information, workshop participants were also keen to enhance collaboration between NMHSs (and related government agencies), which are typically mandated to produce national climate projections, and national/local academic institutions with scientific expertise on climate processes. These institutions, which are currently the main contributors to CORDEX-SEA, have the capability to analyse GCMs and run RCMs. Given the uneven distribution of technical expertise in the region, participants called for the establishment of a regional scientific framework to provide guidance on the generation and usage of climate models. This interaction between NMHSs and academia needs to encompass both the production of the science of climate change and its application at the interface with users in order to achieve the following: (i) synthesize existing national and regional projections, (ii) pool resources and expertise, (iii) build capacity and (iv) formulate policy for sharing data, information and knowledge. This symbiotic relationship would ensure common goals are developed and the needs of users are well addressed across the wide spectrum of stakeholders, including those with established links with NMHSs (e.g. government agencies) and those with connections with universities (e.g. applied scientists).

To facilitate this development, participants agreed WMO has a role to play, being both the reference organisation for NMHSs and the sponsor of the World Climate Research Program (WCRP), under which the global CORDEX program (including CORDEX-SEA) is being coordinated. The fundamental goal of the proposed regional collaborative framework is well-aligned with WMO's vision toward the provision of climate services. Furthermore, the opening of the WMO Regional Office for Region Association II and Regional Association V in Singapore reinforces WMO's growing presence in the region.

Workshop participants were willing to explore the possibility of developing a single platform to facilitate regional coordination on climate services, encouraged in this prospect by examples from outside the region, such as the Copernicus platform developed in Europe. The proposed regional platform is envisaged to be an authoritative and unique data source on issues related to climate change, and should be inclusive of all involved (e.g. NMHSs, academia, and NGOs), thereby enabling the provision of trustable and credible information. The question of sustainability and funding for such development was raised. One possible option is for ASEAN to take the lead, possibly by increasing the role of the existing Asian Specialised Meteorological Centre (ASMC). Other sources of funding, such as the Green Climate Fund, the Asia Pacific Network and the Asian Development Bank, were also proposed. A final proposal to extend the current scope of ASEANCOF to include climate change projections was also strongly supported. An important component of such development would be to build regional capacity and shift away from a reliance on external expertise, particularly in the integration of RCMs, development and analysis of very-high resolution RCMs in the regional context.

Participants also noted that cross-sectorial platforms such as this "*Best Practice Workshop"* provided valuable opportunities to foster regional communication on issues of climate change.

Annex A: List of Participants



Workshop participants' country of origin: number of participants who attended the workshop from the Asia-Pacific region (and from Europe in the insert).

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Annex B: Workshop Programme

Best Practice Workshop on Climate Change Projections and their Applications in ASEAN Countries

20 – 23 March 2018, Singapore

Venue: Quartz Room, Village Hotel Bugis, 390 Victoria Street, Singapore 188061

	Day 1 –Tuesday, 20th of March 2018	
	Welcome and Introduction Chair: Muhammad Hassim Notetaker: Ryan Kang	
08.00 09.00	Registration	
09.00 - 09.50	Opening address	
	Ms Chin Ling Wong, DG, MSS, Singapore	Workshop opening
	Dr Erland Källén, Director, CCRS, Singapore	Welcome address
	Mr Abdalah Mokssit, IPCC, WMO, Geneva	WMO perspective
	Dr Bertrand Timbal, CCRS, Singapore	Workshop overview and objectives
0950-1020	**Group Photo**	
	Coffee break	
	National Climate Projections – NMHs (Continental SEA) Chair: Thea Turkington Notetaker: Ryan Kang	
10.20 10.45	Mr Soim Monichoth, Ministry of Water Resources and Meteorology, Cambodia	Climate Changes Impact on Water Using for Irrigations
10.45 11.10	Mr Sengduangduan Phouthanoxay, Department of Meteorology and Hydrology, Lao PDR	Climate Change and Disaster Preparednes in Lao PDR
11.10 11.35	Dr Zin Mie Mie Sein, Department of Meteorology and Hydrology, Myanmar	Future Projection of summer monsoon rainfall over Myanmar based on CMIP5 data
11.35 12.00	Ms Ruthaikarn Buaphean, Thai Meteorological Department, Thailand	The Experience of Thai Meteorological Department on Climate Projection
12.00 12.25	Dr Nguyen Dang Quang, National Hydro-Meteorological Service of Vietnam, Vietnam	Brief Introduction on Climate Change and Sea Level Rise Projections for Vietnam
1230-1330	**Lunch**	
	National Climate Projections – NMHs (Maritime Continent) Chair: Fredolin Tangang Notetaker: Junhua Yang	
13.30 13.55	Ms Apriliana Rizqi Fauziyah, Meteorological Climatological and Geophysiscal Agency, Indonesia	Climate Change in Indonesia
13.55 14.20	Mr Muhammad Firdaus Ammar bin Abdullah, Malaysian Meteorological Department, Malaysia	Informed Decisions using Climate Change Projections over Malaysia
14.20 14.45	Ms Thelma Cinco, Philippine Atmospheric, Geophysical & Astronomical Services Administration, Philippines	Provision of Climate Projections for the Philippines
14.45 15.10	Dr Chris Gordon, Centre for Climate Research Singapore, Singapore	Singapore's Second National Climate Change Study
1515-1545	**Coffee break**	
	National Climate Projections – Pacific Islands Chair: Geoff Gooley Notetaker: Junhua Yang	
15.45 16.30	Dr Geoff Gooley, CSIRO Mr Salesa Nihmei, Secretariat of the Pacific Regional Environment Programme, Samoa Dr Scott Power, Bureau of Meteorology, Australia	PACCSAP: Regional Approach to Climate Change Science program: Delivery in the Western Tropical Pacific
1630-17.00	General discussion	
17.30	**End of Day 1**	
19.00	**Dinner Reception at Quartz Room, Village Hotel Bugis**	

Day 2 – Wednesday 21st of March 2018 Chair: Marcus Thatcher Notetaker: Muhammad Hassim		
09.00 - 09.30	Dr Geoff Gooley CSIRO, Australia Dr Geoff Gooley, Mr Marcus Thatcher and Ms Thelma Cinco	Lesson(s) learnt from example of national climate change projections work across South-East Asia and Pacific Island nations NMHs – summary of Day 1 Demonstration of the PACCSAP Climate Futures portal and the RCCAP portal.
SEA regional climate projections (I)		
09.30 10.10	Prof Fredolin Tangang CORDEX-SEA chair, Malaysia	Addressing Information Gaps and Data Needs for Adapting to Climate Change in the SEA Region and Building Capcity through the Regional Downscaling SEACLID/CORDEX Project
10.10 10.50	Dr Nicola Golding UKMO, UK	Providing Future Climate Projections: Challenges for SEA
1050-1120	**Coffee break**	
SEA regional climate projections (II) Chair: Kathy McInnes Notetaker: Peter Heng		
11.20 12.00	Dr Marcus Thatcher CSIRO, Australia	CSIRO contribution to deliver regional climate change simulations of relevance to SEA and the Pacific
12.00 12.20	Dr Muhammad Hassim CCRS, Singapore	Singapore's Second National Climate Change Study: regional climate modelling over Southeast Asia with the Unified Model
12.20 12.40	Dr Sri Vijayaraghavan TMSI, NUS, Singapore	High Resolution Dynamical Downscaling over SEA using WRF: Present and Future Climates
1240-1340	**Lunch**	
Key scientific issues of relevance to regional CC projections (I) Chair: Nicola Golding Notetaker: Muhammad Hassim		
13.40 14.05	Dr Ben Horton EOS, NTU, Singapore	Global sea level, past and present and the implications for future projections
14.05 14.30	Dr Kathy McInnes CSIRO, Australia	Sea Level Projections and Extreme Sea Levels for Coastal Applications and Adaptation: examples from Asia, Australia and the Pacific
14.30 14.55	Dr Scott Power BoM, Australia	The El-Nino Southern Oscillation (ENSO) and its Global Impacts over the Coming Century
1500-1530	**Coffee break**	
Key scientific issues of relevance to regional CC projections (II) Chair: Geoff Gooley Notetaker: Peter Heng		
15.30 15.50	Dr Marcus Thatcher CSIRO, Australia	Experiences with Convection Permitting Modelling at CSIRO
15.50 16.10	Dr Muhammad Hassim CCRS, Singapore	Convection permitting simulations: Singapore's experience running the UM model at 1.5km
16.10 16.30	Dr Bertrand Timbal CCRS, Singapore	Climate change Impacts on SEA Monsoonal Seasons
1630 1730	Plenary discussion: "What are the key scientific challenging in delivering Climate Change simulations across SEA?"	
17.30	**End of Day 2**	

1668

Day 3 – Thursday 22nd of March 2018 Chair: Ben Horton Notetaker: Thea Turkington		
09.00 - 09.20	Dr Scott Power BoM, Australia Dr Chris Gordon RA-V WG CLS, Singapore	Lesson(s) learnt from climate change science talks – summary of Day 2 Demonstration of Climate Explorer
Using climate change information – end-user's perspectives (I)		
9.20 9.45	Mr Qingyuan Pang AHA Centre	Climate change and disasters: what we know of the past and present to inform the future
9.45 10.10	Dr Dakshina Murthy Kadiyala ICRISAT	Assessing climate change impacts and adaptation strategies for smallholder agricultural systems in semi-arid regions
10.10 10.35	Mr Sutardi Sudirman Indonesia Water Partnership	The Needs for Best Practices on Climate Change Projections (A Case In Indonesia)
10.35 11.00	Ms Minghui Teo Public Utilities Board, Singapore	Using Climate Change Projections to Assess Impacts for Singapore's Water Utility
1100-1115	**Coffee break**	

Using climate change information – end-user's perspectives (II) Chair: Faye Cruz Notetaker: Thea Turkington		
11.15 11.40	Mr Jack Huang Ministry of National Development, Singapore	Singapore's Approach to Climate Change Resilience
11.40 12.05	Dr Nguyen Dinh Cong Mekong River Commission	Use of climate change scenarios for Mekong Adaptation Strategy and Action Plan in Lower Mekong Basin
12.05 12.25	Dr Jothiganesh Shanmugasundaram RIMES	Enhancing availability of climate information to guide sectoral agencies in adaptation planning
12.25 12.50	Mr Salesa Nihmei Secretariat of the Pacific Regional Environment Programme, Samoa Ms Rosalina De Guzman Philippine Atmospheric, Geophysical & Astronomical Services Administration, Philippines	Case Study from the Pacific-Australia Climate Change Science Adaptation Planning (PACCSAP) Programme and from the Regional Climate Consortium for Asia-Pacific (RCCAP)
1250-1350	**Lunch**	
Discussions on the Climate Change science and its applications across SEA Chair: Chris Gordon Notetaker: Elaine Gao & Thea Turkington		
13.50 15.50	Break-up group discussions: 1) The Climate Change science 2) Application of the CC science	
1550-1610	**Coffee break (and continued discussions)**	
16.10 17.30	Plenary discussion: 1) Report from break-up groups 2) Do we have a consensus emerging about key issues?	
17.30	**End of Day 3**	

Day 4 – Friday 23rd of March 2018 Chair: Bertrand Timbal Notetaker: Anurag Dipankar		
09.00 - 09.30	Dr Chris Gordon RA-V WG CLS, Singapore Dr Sri Vijayaraghavan TMSI, NUS, Singapore	Lesson(s) learnt from the application of the climate change science – summary of Day 3 Uncertainties in Gridded Observations over SEA
Climate change science – future perspective		
09.30 09.50	Mr Abdalah Mokssit IPCC, WMO, Geneva	The upcoming IPCC AR6: what to expect?
09.50 10.05	Prof Fredolin Tangang National University of Malaysia	SEACLID CORDEX Phase 2
10.05 10.20	Dr Nicola Golding UKMO, UK	The Latest Climate Projections for the UK: UKP18
10.20 10.35	Dr Scott Power BoM, Australia	The Climate Change Projection Services Australia Needs – a personal perspective
1035-1100	**Coffee break**	
Using climate change information – Best practice guidelines (I)		
11.00 13.00	Break-up group discussions to identify best practice guidelines: 1) Generating climate change projections 2) Using climate change projections in planning and policy development 3) Benefiting from advances in the climate change science	
1300-1400	**Lunch**	
Using climate change information – Best practice guidelines (II) Chair: Bertrand Timbal & Scott Power Notetaker: Elaine Gao & Anurag Dipankar		
14.00 15.30	Plenary discussion: 1) Report from break-up groups 2) Do we have a consensus emerging about key issues?	
15.30	**Close of the Workshop**	

Annex C: List of Abbreviations

ACCESS	Australian Community Climate and Earth-System Simulator
ADB	Asian Development Bank
AHA Centre	ASEAN Coordinating Centre for Humanitarian Assistance
APHRODITE	Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation
ASEANCOF	ASEAN Climate Outlook Forum
ASMC	ASEAN Specialised Meteorological Centre
AWAP	Australian Water Availability Project
BMKG	Agency for Meteorology, Climatology and Geophysics
BoM	Bureau of Meteorology
CCAM	Conformal Cubic Atmospheric Model
CCRS	Centre for Climate Research Singapore
CCSM	Community Climate System Model
CDAAS	Climate Data Access and Analysis System
CHIRPS	Climate Hazards Group Infrared Precipitation with Station data
CLiDE	Climate Data for the Environment
CLIRAM	Climate Risk Analysis Matrix
CMIP	Coupled Model Intercomparison Project
CNRM	Centre National de Recherches Meteorologiques
CORDEX	Coordinated Regional Climate Downscaling EXperiment
CPM	Convection Permitting Model
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSSP	Climate Science for Service Partnership
DMH	Department of Meteorology and Hydrology
ENSO	El Nino Southern Oscillation
EOS	Earth Observatory of Singapore
ERA	European Reanalysis
ESCC	Earth Systems and Climate Change (ESCC)
ESM	Earth System Model
GCM	Global Climate Model
GDFL	Geophysical Fluid Dynamics Laboratory
GPCP	Global Precipitation Climatology Project
GWP-SEA	Global Water Partnership Southeast Asia
HADGEM	Hadley Global Environment Model
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IMCCC	Inter-Ministerial Committee on Climate Change
IMHEN	Institute of Meteorology, Hydrology and Environment
IPCC	Intergovernmental Panel on Climate Change
IPO	Interdecadal Pacific Oscillation
ITCZ	Intertropical Convergence Zone
LACCAP	Local Climate Change Adaptation Plan
MIROC	Model for Interdisciplinary Research on Climate
MJO	Madden-Julian Oscillation
MMD	Malaysian Meteorological Department

MND	Ministry of National Development
MONRE	Department of Meteorology and Hydrology
MOWRAM	Ministry of Water Resources and Meteorology
MPI	Max Planck Institute for Meteorologie
MRC	Mekong River Commission
MRI	Meteorologicla Research Institute
MSS	Meteorological Service Singapore
NAP	National Adaptation Plan
NCAR	National Centre for Atmospheric Research
NESP	National Environmental Science Programme
NMHS	National Meteorological and Hydrological Services
PACCSAP	Pacific-Australian Climate Change Science Adaptation Planning
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PCCSP	Pacific Climate Change Science Programme
PDO	Pacific Decadel Oscillation
PRECIS	Providing Regoinal Climates for Inpact Studies
PUB	Public Utilities Board
RCCAP	Regional Climate Consortium for Asia and the Pacific
RCCDF	Regional Climate Projections Consortium and Data Facility
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
RegCM	Regional Climate Model
RIMES	Regional Integrated Multi-Hazard Early Warning System for Africa and Asia
RU-CORE	Ramkhamhaeng University Centre of Regional Climate Change and Renewable Energy
RWG	Resilience Working Group
SACA&D	Southeast Asian Climate Assessment & Dataset
SARCCIS	Southeast Asian Regional Climate Change Information System
SEACAM	Southeast Asia Climate Analysis and Modelling
SEACLID	Southeast Asia Regional Climate Downscaling
SPREP	Secretariat of the Pacific Regional Environment Programme
TMD	Thai Meteorological Department
TMSI	Tropical Marine Science Institute
TRMM	Tropical Rainfall Measuring Mission
UKM	National University of Malaysia
UKMO	United Kingdom Meteorological Office
UM	Unified Model
VIA	Vulnerability Impact Assessment
WACDEP	Water, Climate and Development Program
WCRP	World Climate Research Programme
WG-CLS	WMO RA V Working Group on Climate Services
WMO	World Meteorological Organisation
WRF	Weather Research and Forecasting Model